David Dent

The WINAND STARING CENTRE for Integrated Land, Soil and Water Research

# Landforms and Soils of Marsabit District, Kenya

## A site evaluation for Rangeland use

L. Touber

Report 3

Wageningen (The Netherlands), 1990

Landforms and Soils of Marsabit District, Kenya

Survey carried out for:

The Range Management Handbook Project (RMHP), G.T.Z. and the Ministry of Livestock Development, Nairobi, Kenya

# LANDFORMS AND SOILS OF MARSABIT DISTRICT, KENYA

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ABSTRACT

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Within the framework of the Range Management Handbook Project, Kenya, an inventory of landforms and soils at 1 : 1 000 000 scale of Marsabit District has been carried out. It concerns a site evaluation for rangeland use, which is based on a limited amount of field observations, and relies heavily on visual interpretation of satellite imagery.
The physical data of landforms and soils are interpreted for aspects of primary production (fertility and soil-water relationships) and for managements aspects (erosion status and hazard; accessibility for livestock; flooding hazard; possibilities for construction of dams and waterpans).
Annex I deals with the organizational and logistic aspects.

Keywords: Kenya, Marsabit District, Landforms, Soils, Range
Management, satellite image interpretation.

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# 1 INTRODUCTION

The present survey report deals with the physical environment of Marsabit District. This inventory is part of the range potential assessment of the arid and semi-arid lands of Kenya, in the context of the production of a Range Management Handbook (RMH) for the Ministry of Livestock Development. Time constraints have necessarily restricted the density of the field observations. Satellite image interpretation plays an important role. Field checks were limited in number and directed towards the assessment of range potential, rather than towards the execution of a conventional "multi purpose" soil survey. Hence it is preferred to use the term "Site evaluation for rangeland use".

The RMH project document calls for information that is accessible to professionally non-related staff of the Range Division of the Ministry. As much as possible therefore this report avoids technical/pedological terminology.

Survey results present the major limitations of the abiotic environment to range potential and their distribution in Marsabit District. These data will have to be merged with climate and vegetation data to arrive at the estimation of sustainable stocking rates and for the range management units to be established.

# 2 METHODOLOGY OF DATA GATHERING AND RESULTS

The gathering of soil data in a natural resources inventory excercise comprises routine-wise the following three steps:
- collection of existing data in literature and the interpretation of available remote-sensing material
- field survey work
- Elaboration of data; production of maps, legends and report.

The way these three phases, and especially the fieldwork, are implemented, depends wholly on time and manpower available. The present survey was scheduled to be finalized in three months time out of which four weeks were available for field checks. For an area as vast as Marsabit District a field survey will be necessarily of a very low intensity, i.e. only a limited number of field observations per unit area can be made.

Also, the kind of observations are geared towards evaluation for extensive range, rather than to the compilation of a comprehensive multi-purpose reconnaissance soil survey.

## 2.1 Previous surveys and remote sensing data

Of existing data use has been made of the 1 : 1 Million scale Exploratory Soil Map of Kenya (Sombroek, 1982). Of the southern part of the District a lot of data exist due to the Unesco's IPAL project, of which readily available are a soil map at 1 : 250.000 (Van Kekem, 1986); a 1 : 500.000 scale soil erosion map (Bake, 1983) and a range type map (Lusigi et al. , 1983). Sombroeks and Van Kekems publications proved most useful.

Crucial for the implementation of small scale inventories, is the use of aerial photographs or satellite imagery.

Soil inventories of large areas that are presented on very small scale maps, such as those at 1 : 1 Million, have necessarily to rely heavily on the interpretation of remote sensing data. Time constraints and difficulties in accessibility make it impossible, even in surveys of a much larger scale (eg. 1 : 100.000) to visit for instance all points of a regular grid system, and make a soil observation every 100 or 1000 meters.

The interpretation of aerial photographs or satellite images provides the opportunity to select a limited number of points in the field in a strategical way, such that the data of these field observation points are representative for large tracts of land.

In the present survey, of which the area covers about 200 x 300 km2, the use of aerial photographs is too costly and too time

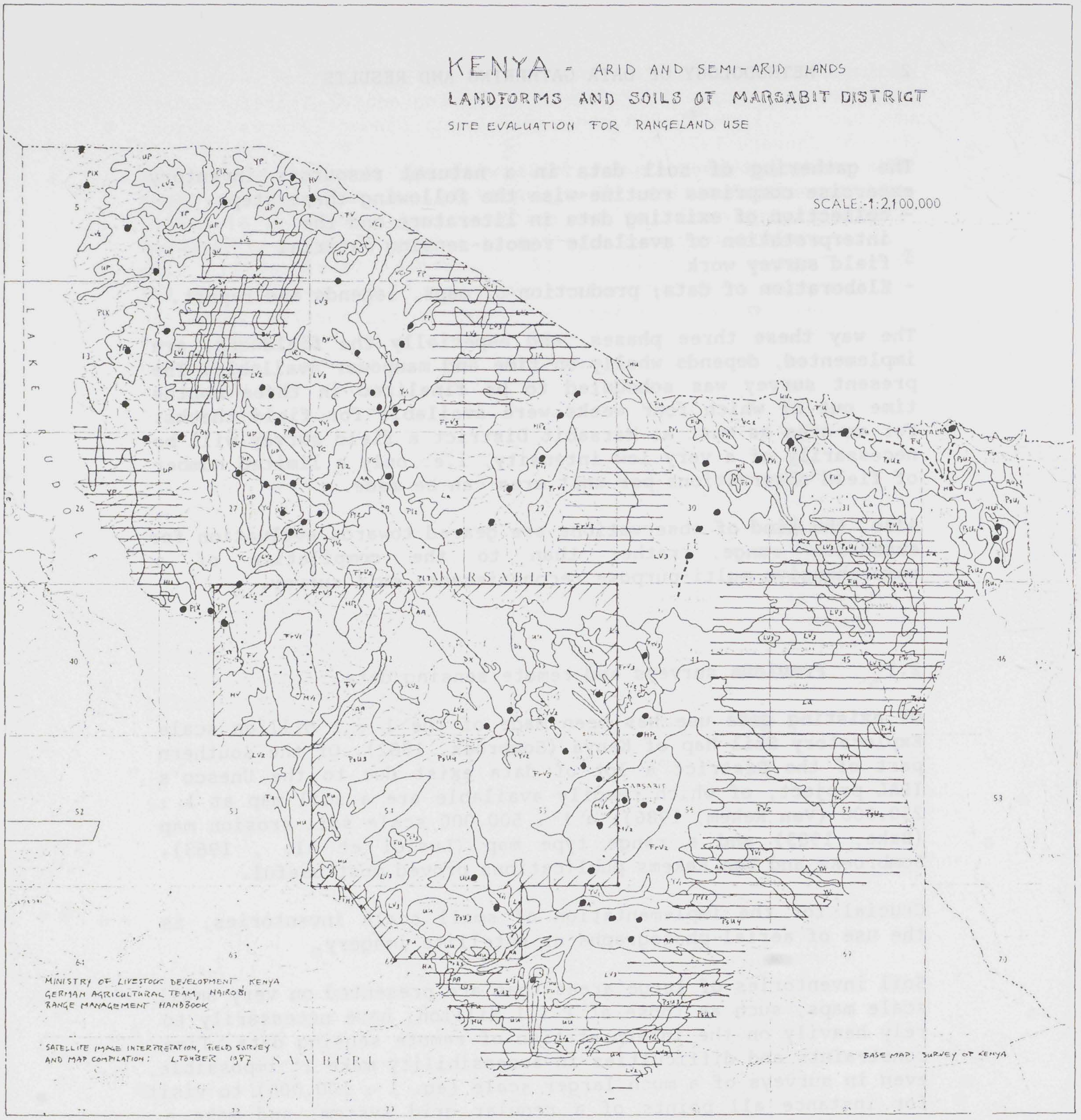


fig 1. DISTRIBUTION OF OBSERVATION POINTS

- LOCATION OF OBSERVATION POINT

AREA WITH RELATIVELY LOW DENSITY OF FIELD OBSERVATIONS

LOCATION OF RECONNAISSANCE SOIL MAP OF THE MT. KULAL-MARSABIT AREA (VAN KEKEM, 1986) consuming. (Existing photographs are at scale of 1 : 60.000, which means a coverage of ± 1000 photographs.) Therefore use was made of 1 : 500.000 scale prints of Landsat Images, which date of January 1976.

## 2.2 Field survey work

Fieldwork was conducted in four weeks time, by a team consisting of a range specialist/team leader; a vegetation consultant and a soil survey consultant. As many as possible representative points were visited by travelling along all existing motorable tracks. In some cases the oil-drilling companies exploration lines were followed, using compass and car mileage counter. Use was made of 1 : 250.000 scale topographic sheets (Survey of Kenya) together with the Landsat Images for orientation.

At each observation point was recorded: landform, geology, slope, stoniness/rockiness, apparent soil degradation and topsoil quality (grass cover, organic matter content, "sealing" of the surface), status of erosion (sheet erosion, overwash, gully erosion, tunnel erosion, wind erosion, wind deposition), Further soil depth, soil texture, soil colour, consistence and calcareousness. In a number of cases topsoil samples were taken for fertility analysis and soil salinity.

It was considered too time consuming and not altogether relevant to make soil profile pits. Soil augerings were made in a limited number of cases, most soils being too stony.

See fig. 1 for the distribution of observation points.

## 2.3 Elaboration of data

Elaboration of field data was initiated by drawing final landforms/soils boundaries on a 1 : 500.000 scale mosaic of landsat images, together with the preparation of a legend.

The legend follows the set-up as in use by the Kenya Soil Survey, i.e. an entry of Major Landforms (Mountains; Footslopes; Plains, etc.) and at second level Geology (Basement System Rocks, Volcanic Rocks, Lake bed deposits, etc). At the third level these units are divided again according to the local topographic conditions and prevailing soil qualities as observed in the field.

The units are described in terms of predominant slope steepness; erosion hazard; accessibility to livestock, flooding hazard, soil drainage, -depth, -colour, salinity/sodicity, rockiness and stoniness, texture, infiltration capacity and topsoil organic matter content.

Map compilation was accomplished by the production of a provisional 1 : 500.000 scale soil map, traced from the Landsat Mosaic onto a transparent 1 : 500.000 scale copy of a USA "operational navigation chart", available at KSS. This 1 : 500.000 scale soil map was simplified and reduced by means of an optical pantograph to the present 1 : 1 Million scale version. The provisional 1 : 500.000 scale map with legend and description of its 58 units, is available at GAT as internal document. The final 1 : 1 Million map shows 36 units and serves as the basis for further data interpretation and rangeland evaluation.

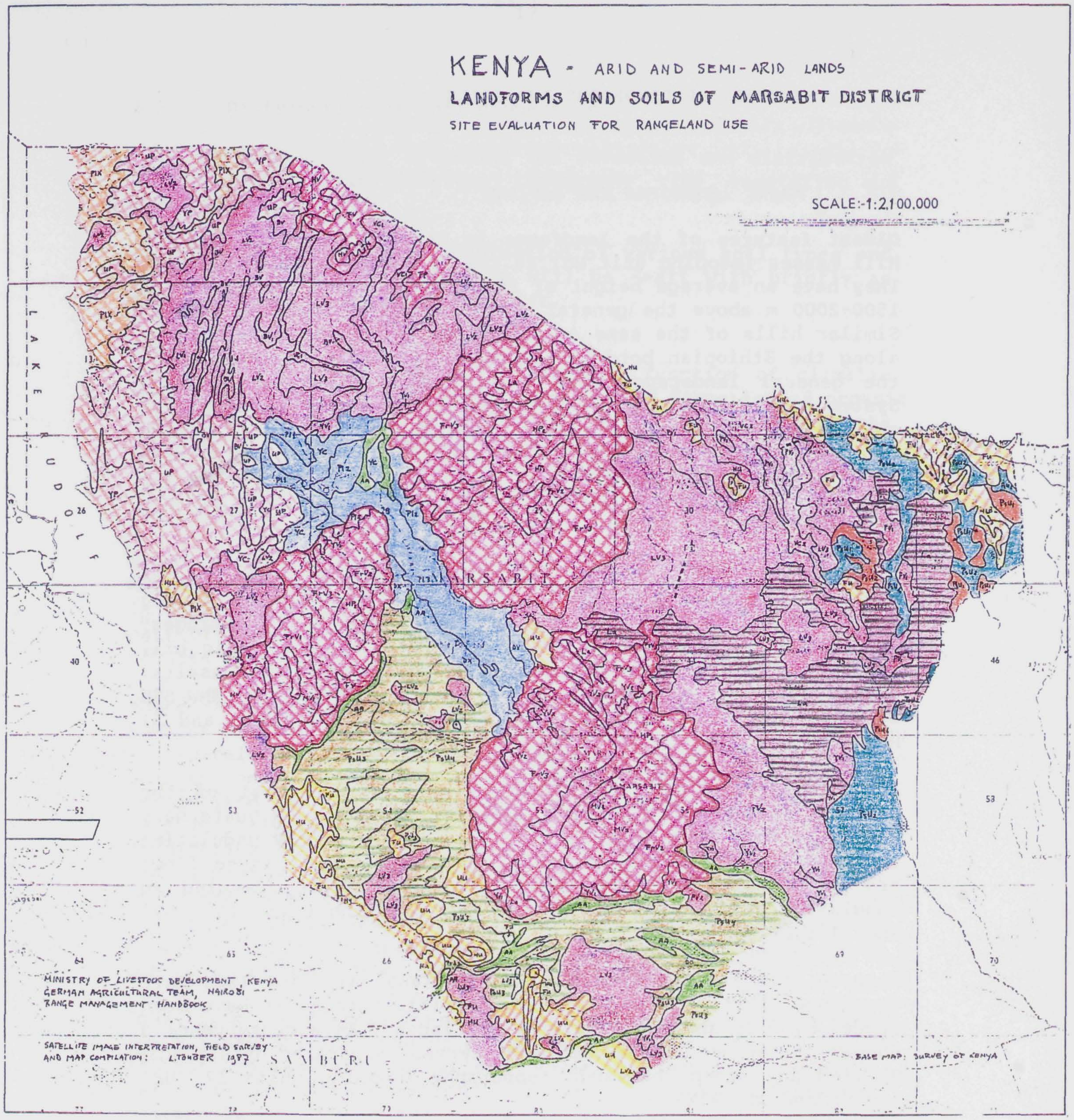


fig. 2 **SUMMARY OF LANDFORMS**

LANDFORMS DEVELOPED ON BASEMENT SYSTEM ROCKS

- HILLS, FOOTSLOPES, UPLANDS
- EROSIONAL PLAINS ("RED SAND" PLAINS)

LANDFORMS DEVELOPED ON VOLCANIC ROCKS

- LARGE HILL MASSES OF MT. KULAL, MARSABIT, HURRI HILLS
- BASALT PLATEAUS AND PLAINS, PARTLY STEPFAULTED
- UPLANDS AND PIEDMONT PLAINS ON PYROCLASTIC ROCKS AND DERIVED SEDIMENTS
- RECENT AND SUBRECENT LAVAFLOWS

LANDFORMS DEVELOPED ON SEDIMENTS OF VARIOUS ORIGIN

- PIEDMONT PLAINS DEVELOPED ON ALLUVIUM PREDOMINANTLY DERIVED FROM BASEMENT ROCKS
- SEDIMENTARY PLAINS: ("GREYCLAY" PLAINS)
- LACUSTRINE PLAINS: LAKE BEDS, LAKE BED TERRACES, DUNE FIELDS OF CHALBI DESERT
- BADLANDS AND PIEDMONT PLAINS IN TARU / TURKANA GRITS
- ALLUVIAL VALLEYS; FLOODPLAINS

# 3 SUMMARY OF LANDFORMS AND SOILS

## 3.1 Major landforms and geology

Oldest features of the landforms in Marsabit District are the hill masses (mapping unit HU) at the SW border of the District. They have an average height of 2000-2500 m above sea level and 1500-2000 m above the general level of the surrounding plains. Similar hills of the same age occur to the north-eastern part, along the Ethiopian border, although of lesser elevation above the general landscape. They consist of Precambrian Basement System Rocks. These hill masses are not important in terms of surface extent. They are important water cathment areas, however and are the source of the sediments of which their surrounding footslopes are built (mapping unit 10: FU) and of most of the extensive sedimentary plains in the southern part of the district (mapping unit 26: PsU3 and 27: PsU4).

More important hill masses are formed by the Kulal, Asie, Marsabit and Hurri (mapping units 1 and 2: MV and 4 and 5: HP) and their surrounding slopes and lavaflows or "Footridges" (mapping units 7: FrVl, 8: FrV2, 9: FrV3). These volcanic hill masses are of Pleistocene age and consist mainly of basalts. Hurri, Asie and Marsabit show in their top-region a NNW-SSE stretching zone of volcanic ash cones (mapping units 4 and 5: HP).

At the general level of elevation most of the rest of the District is occupied by basalt flows of Tertiary and Quaternary age. They form a vast and almost flat to very gently undulating landscape (mapping unit 15: LV3). Towards the West these flows are partly broken by N-S stretching rift faults, causing an undulating and step-faulted topography (mapping units 13 : LVl and 14 : LV2).

Between this faulted area and Lake Turkana, alluvial fans have developed, that, in the process of uplift, themselves have been eroded by deep and broad gullies or "lagas". As a consequence a number of terrace levels can be discerned, separated by strongly gullied and steep "badland" topography (mapping units 17: UP, 18: YP and 31: PlX).

Extensive lavaflows of more recent age stretch NE of Marsabit towards the Eastern border. It features as an inhospitable, rugged and very rocky landscape (mapping unit 36: La).

The central part of Marsabit district is formed by the Chalbi Desert, a dried-out lake bed: a flat, salt crusted surface, devoid of vegetation (mapping unit 30: Pl3).

See fig. 2 for a strongly generalized and simplified distribution of major landforms.

## 3.2 Distribution of soil properties

The main factors that determine the formation and distribution of soils are climate, rocktype, topography, time, vegetation and human influence.

In order to explain the distribution of various soil types and their properties, these factors will be dealt with briefly as they are found in Marsabit District.

**Climate**

The amount of plant growth is largely a function of climatic conditions, and with this "phytobiomass" the formation of organic matter in the top soil is strongly related. The more moist the climate, the more organic matter in the soil. Organic matter is very beneficial to the quality of the soil, especially in respect to infiltration and water storage capacity; and hence also to resistance to erosion.

Areas of higher rainfall, like the top regions of Kulal, Marsabit and Hurri hill masses, show an organic matter content in their top soils of 1.5 to over 2%. However the very dry major part of the District, has soils with an organic matter content of less than 0.5% in the topsoil.

Where rainfall dominates evaporation, like in tropical forests such as Marsabit National Park and Mt. Kulal, there is a leaching of mineral salts from the soils with the surplus rainwater. Where evaporation is predominant over rainfall, mineral salts are not washed from the soil but may be even residually enriched. This is especially the case in areas that receive floodwaters, usually originating from rainfall elsewhere, carrying amounts of salts and sediments. Especially the lowest parts, of the landscape where the water stagnates, evaporation leaves the salts behind. The Chalbi Desert (mapping unit 30: Pl3) is the result of such a process: a saline area where plant growth is virtually absent due to toxic quantities of salt in the soil.

Apart from these areas where floodwaters assemble (mapping units 30: Pl3 and 32: AA), the major part of the District has, due to its hot and semi-arid conditions, soils that are rich in mineral salts; of basic reaction (pH 7-8.5) and are in general strongly calcareous.

**Geology**

Rocktype or geological composition determines the so-called parent material from which the soils develop.
On the landforms and soils map, the legend mentions mainly three types of rock:

1 Undifferentiated volcanic rocks, mainly basalts. These are a fine-grained rock type, relative poor in quartz and rich in ferro-magnesian minerals, so that the weathering products (soils

and sediments derived from these rocks) are mainly red or reddish coloured clays and clay loams. Further, most units on undifferentiated volcanic rocks show to a lesser or stronger degree stoniness or boulders at the surface, a typical feature for these geological formations.
All these units on undifferentated volcanic rocks are indicated with a V as second capital letter in the unit symbol.
2. Another important volcanic rock type are the Pyroclastic rocks (all P-units). These are volcanic ashes, usually producing coarse grained, fine gravelly soils of high permeability and infiltration rates.
3. The Basement System rocks and sediments derived from these (all U-units) contain more sand particles and are poorer in ferromagnesian minerals. The soils developed on this parent material are more brownish coloured coarse sandy loams and coarse sandy clay loams.

The division of the Marsabit soils according to parent material is very important as they show marked differences in textural composition, clay mineralogy and chemical properties, as well as in behaviour to erosional processes (See further Chapter 5, para 5.4).

**Time**
Time, in the geological order of magnitude, determines the duration of processes of weathering and soil formation. This is illustrated in Marsabit District by the lava-basalt flows that range in age from early-tertiairy to sub-recent. The youngest ones show little or no weathering and soil formation and feature as inaccessible rock and boulder fields (mapping unit 36: La) while the oldest ones have a very deep cracking clay soil, with only locally stones and boulders (mapping unit 15: LV3).

**Topography**
Topography exerts its influence through slope steepness, whereby erosion through runoff of rainwater can gain momentum. Higher and steeper parts of the landforms have often shallow rocky soils (mapping units 3: HU, 7: FrV1, 8: FrV2, 16: UU, 17: UP, 14: LV2) while the extensive flat and very gently undulating land tends to have a much deeper soil mantle (mapping units 15: LV3 and 22: PV1). At the foot of steep hills and scarps eroded material may accumulate and form the substratum for a deep thick soil (mapping unit 10: FU). Also this eroded material has been transported and sedimented into larger, almost flat areas, depressions or bottomlands, where consequently as well deep soils are found, free of rocks or stones (mapping units 19-20: YV; 24-30: PsU- and Pl-units; and 32: AA and 33:, BV).

Topography has its influence also on drainage of soils: the possibility for water to flow off or seep through in the more elevated parts, where consequently also dissolved weathering products (nutrients) are leached. In downslope positions, where flooding or ponding may occur, there is an accumulation of sediments and plant nutrients (see also climate: salinity/-sodicity).

**Vegetation**
Plant growth and litter production has an important influence on the top soil and soil surface qualities by the supply of organic matter. The humus content determines largely the capacity of the soil to allow overgrazed areas to recuperate within a foreseeable future.
The lack of this organic matter in the very dry areas is (apart from, or inherent to, the climatic factor) the main cause of the fragility of the topsoils, and consequent sensitivity to over-utilisation.

**Human influence**
Human influence on soils in Marsabit District is manifest only locally by the effects of accelerated erosion. The concentrated presence of livestock around permanent watering points is an obvious example. Various forms, degrees and the consequences of human-induced erosion will be dealt with in Chapter 5.4.

# 4 DESCRIPTION OF MAPPING UNITS

## 4.1 Introduction to the map legend symbols

The mapping unit symbols are built up of two capital characters, the first one indicative of the major landform it represents; the second denominating the geology or parent material. A third digit (number) simply differentiates within a landform/geology unit according to local topography and/or soil type.

The sequence of units is chosen according to topographic position: from high (mountains) to low (alluvial plains) in landforms; and from old to young (as far as known) in geology.

The system is adapted from the one in use by the Kenya Soil Survey (Kenya Soil Survey Staff, 1987).

Symbols denominate the following;

| | | | |
|---|---|---|---|
| M | Mountains | U | Basement system rocks, undifferentiated |
| H | Hills | | |
| Fr | Footridges of major volcanoes | V | Volcanic rock, undifferentiated |
| F | Footslopes | | |
| L | Plateaus | P | Pyroclasic rocks, volcanic ashes |
| U | Uplands | | |
| Y | Piedmont plains | A | Alluvial deposits, undifferentiated |
| p | Plains, undifferentiated | | |
| Ps | Sedimentary plains | X | Material of various origin |
| Pl | Lacustrine plains | | |
| A | Alluvial plains | | |
| B | Bottomlands | | |
| Vc | Valley complex | | |
| D | Dunes | | |
| La | Recent Lavaflows | | |

## 4.2 Mapping units

### Mapping unit 1: **MV1**

| | |
|---|---|
| Surface area | : 142 km2; 0.2% of total District area |
| Geology | : Undifferentiated tertiairy volcanic rocks-mainly basalts and pyroclastic rocks |
| Relief, Topography | : Hilly to rolling topograhy. Slopes over 30% common. Relief intensity locally over 300 m. |
| Vegetation; landuse | : Forest, partly National Park |
| Soils | : Well drained, very deep to shallow dusky red to dark reddish rown friable clay loam to clay, in steep places mostly bouldery and stony |
| Condition of topsoil | : Thick, humus rich, well structured top soil with good vegetative cover. High infiltration capacity of surface soil, high resistance to erosion |
| Erosion hazard | : Potential hazard of gully development after clearing of vegetation, especially at steeper slope parts |
| Accessibility for livestock | : Locally severe restrictions for cattle, mainly due to slope steepness |

### Mapping unit 2: **MV2**

| | |
|---|---|
| Surface area | : 995 km2; 1.5% of total District area |
| Geology | : Undifferentiated tertiary volcanic rocks-mainly basalts, conglomerates and some ash deposits. |

| | | |
|---|---|---|
| Relief, Topography | : | Rolling to undulating "high-lands", occasional river courses deeply entrenched |
| Vegetation; landuse | : | Croton woodland and Combretum bushland. Themeda and chrysopogon grassland. Intense cultivation, rainfed, smallholders |
| Soils | : | Well drained, very deep, dusky red to dark reddish brown friable clay loam to clay, in places bouldery and stony. |
| Condition of topsoil | : | High organic matter content under uncultivated conditions. High infiltration capacity. High "recuperation" capacity after over grazing |
| Erosion hazard | : | Low sheet erosion hazard. Gully development imminent along cattle tracks. Moderate winderosion hazard under high grazing pressure. |
| Accessibility for livestock | : | No restrictions. |

Mapping unit 3: **HU**

| | | |
|---|---|---|
| Surface area | : | 813 km2; 1.2% of total District area |
| Geology | : | Precambrian Gneisses, undifferentiated Basement System rocks |
| Relief, Topography | : | Hilly to mountainous topography. Irregular, in many places precipitous slopes and giant rock outcrops |
| Vegetation; landuse | : | Nil (rock outcrops) or bushland |
| Soils | : | Rock outcrops and well drained, shallow dark reddish brown, friable, rocky and stony sandy loam to sandy clay loam |
| Condition of topsoil | : | Where present, moderately rich in organic matter and primary weatherable minerals |

| | | |
|---|---|---|
| Erosion hazard | : | Sensitive to sheet and gully erosion after removal of vegetation, mainly due to slope steepness and shallowness of soils |
| Accessibility for livestock | : | Severe constraints. Accessible only locally to goats. |

Mapping unit 4: **HP1**

| | | |
|---|---|---|
| Surface area | : | 141 km2; 0.2% of total District area |
| Geology | : | Relatively fine-grained pyroclastic material: volcanic ash of fine-gravel size |
| Relief, Topography | : | Many isolated small volcanic cones, among gently undulating "highlands" |
| Vegetation; landuse | : | Erithrina and Acacia wooded grassland of Themeda, Pennisetum, and Chrysopogon species. |
| Soils | : | Well to somewhat excessively drained, moderately deep, dark brown fine gravelly sandy clay loam, in places stony and gravelly. |
| Condition of topsoil | : | Relatively rich in organic matter, well structured surface soil with high infiltration capacity. Rapid regrowth of vegetation after over-utilisation. |
| Erosion hazard | : | Slight to moderate wind erosion hazard |
| Accessibility for livestock | : | Steepness of volcanic cones poses some constraint to the accessibility for cattle and camel. |

Mapping unit 5: **HP2**

| | | |
|---|---|---|
| Surface area | : | 1756 km2; 2.6% of total District area |

| | |
|---|---|
| Geology | : Volcanic ashes and fine-grained pyroclastic material |
| Relief, Topography | : Gently undulating highland, with numerous small, straight sloped hills (ash cones) |
| Vegetation; landuse | : Bushed grassland of Acacia mellifera and Acacia tortilis over mainly Chrysopogon grasses |
| Soils | : Well to somewhat excessively drained moderately deep, brown, locally stony, fine gravelly sandy clay loam |
| Condition of topsoil | : Moderately high in organic matter. High infiltration rate |
| Erosion hazard | : Low sheet and moderate gully erosion hazard under high grazing pressure. Good possibilities for recuperation of vegetation. Locally strong sheet erosion over shallow calcrete formation. |
| Accessibility for livestock | : Moderate restrictions for cattle due to stoniness and steepness of terrain. |

Mapping unit 6: **HV**

| | |
|---|---|
| Surface area | : 518 km2; 0.8% of total District area |
| Geology | : Undifferentiated volcanic rocks, mainly basalts |
| Relief, Topography | : Hilly and rolling topography, locally stepfaulted. Scarps and precipitous slopes common |
| Vegetation; landuse | : Mainly sparse annual grassland with locally scattered bush |
| Soils | : Well to somewhat excessively drained, shallow, dark reddish brown calcareous, extremely stony, bouldery and rocky clayloam |

| | | |
|---|---|---|
| Condition of topsoil | : | In the drier zones degraded to mere boulder mantle over weathered rock. In the semi-arid zones (Sabarei) low in organic matter and sensitive to degradation |
| Erosion hazard | : | Already degraded areas carry a protective stone mantle. Otherwise considerable sheet and gully erosion hazard |
| Accessibility for livestock | : | Only for goats there may be some possibilities to enter into the area |

Mapping unit 7: **FrV1**

| | | |
|---|---|---|
| Surface area | : | 514 km2; 0.8% of total District area |
| Geology | : | Undifferentiated volcanic rocks; mainly basalts with locally admixture of pyroclastic material |
| Relief, Topography | : | Slopes of Mt.Kulal: gentle to irregular slopes of up to 8%, intersected by numerous steeply incised river gorges (slopes over 30%) |
| Vegetation; landuse | : | Deciduous woodland with dwarfshrub understory of Duosperma eremophilum |
| Soils | : | Well drained shallow to moderately deep dark reddish brown, friable, locally calcareous, stony to very bouldery clay loam to clay |
| Condition of topsoil | : | Moderate amount of organic matter content and moderately rich in nutrients. Soils with capacity to regenerate vegetation after overgrazing |
| Erosion hazard | : | Strong gully development possible upon eventually overutilized areas |

| | | |
|---|---|---|
| Accessibility for livestock | : | Severely limited by the numerous steeply incised river courses. Along the relatively smooth crests, stoniness and boulders reduce the accessibility for cattle. |

Mapping unit 8: **FrV2**

| | | |
|---|---|---|
| Surface area | : | 1612 km2; 2.4% of total District area |
| Geology | : | Undifferentiated volcanic rocks, mainly basalts |
| Relief, Topography | : | Lower slopes of Marsabit, Asie and Hurri hill masses. Overall slopes from 5% uphill to less than 2% at outer edges. Steeply incised stream-courses |
| Vegetation; landuse | : | Deciduous shrubland and bushed grassland of Acacia mellifera, Acacia reficiens over annual and perennial grasses |
| Soils | : | Imperfectly to moderately well drained deep, dark brown, locally saline and sodic, locally stony and bouldery, cracking clay |
| Condition of topsoil | : | Well structured top soil, low in organic matter content |
| Erosion hazard | : | Possibly severe gully erosion and tunnel erosion hazard. Presently at over utilized areas slight sheet erosion and wind erosion. In the neighbourhood of steeply dissected stream courses stronger erosion features |
| Accessibility for livestock | : | Slight to moderate restrictions for camel and cattle due to local stoniness, surface boulders and deeply entrenched rivers |

Mapping unit 9: **FrV3**

| | | |
|---|---|---|
| Surface area | : | 8955 km2; 13.3% of total District area |

| | | |
|---|---|---|
| Geology | : | Tertiairy lavaflows. Lower volcanic stopes of Marsabit, Kulal Asie and Hurri hill masses, mainly basalts |
| Relief, Topography | : | Overall slopes from 5% uphill to less than 2% at lower edges. Complex of steeper and flatter local topography due to irregular lavaflow morphology |
| Vegetation; landuse | : | Deciduous shrubland of Acacia mellifera and A. reficiens, with, depending on altitude, Chrysopogon or annual grassland of mainly Tetrapogon and Aristida species |
| Soils | : | Complex of well to imperfectly drained, shallow to deep, dark reddish brown, calcareous, locally saline, locally very stony, bouldery and rocky clay loam to clay, with many rock outcrops and in many places an extremely stony and bouldery surface. |
| Condition of topsoil | : | The surface soil is generally low (at higher elevation) to very low (in hotter parts) in organic matter content |
| Erosion hazard | : | Soils material is mainly found as pockets of colluvium in the depressions of the irregular rock and boulder topography. Sheet and gully erosion will therefore develop only depending on local situation. Wind erosion causes the formation of a desert pavement easily at heavily frequented areas (e.g. north of Kalacha), as the loose layer of very fine and light soil material is easily picked up by the wind |
| Accessibility for livestock | : | Moderate to severe restrictions for cattle and to a lesser extent to camels, due to the often rugged rocky topography and surface stones and boulders |

Mapping unit 10: **FU**

| | |
|---|---|
| Surface area | : 1821 km2; 2.7% of total District area |
| Geology | : Colluvium derived from undifferentiated Basement System rock |
| Relief, Topography | : Gentle, concave to straight, long slopes of 8-2% |
| Vegetation; landuse | : Mostly deciduous bushland, or bushed grassland of Commiphora, Delonix sp. and Acacia mellifera over annual and perennial grasses |
| Soils | : Well drained, very deep, dark reddish brown friable to firm sandy clay loam to sandy loam |
| Condition of topsoil | : Undisturbed soils have a moderate to high infiltration capacity.<br>Soils tend to be sensitive to over utilization, where sealing of the surface prevents a rapid recuperation of the vegetation cover |
| Erosion hazard | : Soils sealing means a strong reduction in infiltration capacity and hence a rapid increase of sheet erosion. Also ravine-like gully development is not uncommon on these footslopes, due to vegetation disturbance uphill |
| Accessibility for livestock | : There are restrictions to accessibility for cattle and camel due to locally dense shrub cover |

Mapping unit 11: **FP**

| | |
|---|---|
| Surface area | : 293 km2; 0.4% total District area |
| Geology | : Volcanic ash deposits and fine pyroclastic material, partly colluviated |

| | |
|---|---|
| Relief, Topography | : Concave regular slopes of 5-1% (Due to mapping scale also the volcanic cones, with which these footslopes are associated, are included) |
| Vegetation; landuse | : Annual sparse grassland and dwarfshrubs, mainly Indigofera, Heliotropium |
| Soils | : Well to somewhat excessively drained, moderately deep to shallow, brown, very friable, strongly calcareous, fine gravelly clay loam, with calcrete formations at various depths |
| Condition of topsoil | : Under the given extremely dry conditions these soils have moderately high organic matter content and a reasonable infiltration capacity |
| Erosion hazard | : Due to the high amount of fine volcanic ash the area is however sensitive to wind erosion, when under heavy grazing pressure. Presently there is evidence of slight sheet erosion and some accumulation of windblown deposits around dwarf shrubs |
| Accessibility for livestock | : No restrictions as to the accessibility for livestock |

Mapping unit 12: **FV**

| | |
|---|---|
| Surface area | : 585 km2; 0.9% of total District area |
| Geology | : Colluviated deposits of volcanic origin, locally Basement System material present (Sabarei area) |
| Relief, Topography | : Gentle overall slope of 8-2%, in many places gullied |
| Vegetation; landuse | : Mainly deciduous bushland of Acacia species |

| | | |
|---|---|---|
| Soils | : | Well drained, very deep dark reddish brown calcareous, very gravelly and stony sandy loam, with a very stony surface |
| Condition of topsoil and Erosion hazard | : | The stone concentration and sealing at the soil surface, the frequent gullies and the development of bushland thicket in many places are all signs of soil degradation and accelerated erosion. |
| Accessibility for livestock | : | Moderate restrictions for camel and cattle due to surface stoniness, gullied topography and dense bush |

Mapping unit 13: LV1

| | | |
|---|---|---|
| Surface area | : | 310 km2; 0,5% of total District area |
| Climate | | |
| Geology | : | Basalts |
| Relief, Topography | : | Plateau; i.e. an almost flat elevated area, bordered by an escarpment |
| Vegetation; landuse | : | Probably bushed grassland*) |
| Soils | : | Most probably similar to those of mapping unit 15: LV3: i.e. moderately well drained very deep reddish brown cracking clay*) |
| Condition of topsoil | : | The relatively elevated position and dense pattern of cattle tracks suggest a fairly productive soil in good condition*) |
| Erosion hazard | : | Low, mainly due to almost flat topography and favourable vegetation cover. Possibly moderately sensitive to wind erosion |

| | | |
|---|---|---|
| Accessibility for livestock | : | Locally slight restrictions for cattle, due to surface stoniness. The surrounding escarpment is a prohibitive barrier to movements beyond the area |

*) no field observations. Data inferred from view during reconnaissance flight.

Mapping unit 14: LV2

| | | |
|---|---|---|
| Surface area | : | 4380 km2; 6.5% of total District area |
| Geology | | Basalt |
| Relief, Topography | : | Partly stepfaulted basalt plateau: i.e. due to geological faultlines an undulating topography of north-south stretching ridges and depressions |
| Vegetation; landuse | : | Mainly deciduous bushland of Acacia mellifera, A. reficiens and Boswellia Sp. |
| Soils | : | Well drained soils of various depths, with frequent rock outcrops. Mainly very stony and bouldery, clay loam to cracking clay |
| Condition of topsoil | : | Mainly low in organic matter content; loose and very friable consistence |
| Erosion hazard | : | In connection with the topography the locally cracking clay may give rise to tunnel erosion development, and eventual gullies |
| Accessibility for livestock | : | Stones and boulders and terrain steepness wil locally strongly hamper the accessibility for cattle, and to a lesser extent for camels |

| | | |
|---|---|---|
| Mapping unit 15: LV3 | | |
| Surface area | : | 7531 km2; 11.2% of total District area |
| Geology | : | Basalts |
| Relief, Topography | : | Very gently undulating to almost flat; slopes not exceeding 2% |
| Vegetation; landuse | : | Annual grassland of Tetrapogon and Aristida (locally in moister climate reach: Lintonia) and Bushland, associated with bouldery soils |
| Soils | : | Moderately well drained, very deep, dark reddish brown, calcareous, locally cracking clay to clay loam, with a stony surface, locally very stony and bouldery |
| Condition of topsoil | : | Due to climate conditions a low organic matter content of the top soil. Loose and very friable consistence |
| Erosion hazard | : | Loose surface soil is sensitive to wind erosion. The process of deflation under heavy livestock traffic has led to 100% bare stone cover in a wide area around Balesa waterhole |
| Accessibility for livestock | : | Where surface boulders and stones occur, there is a moderate restriction for cattle |

| | | |
|---|---|---|
| Mapping unit 16: UU | | |
| Surface area | : | 1282 $km^2$; 1.9% of total District area |
| Geology | : | Undifferentiated Basement System rock, mainly Precambrian Gneisses.<br>In places rich in ferromagnesian minerals |

| | |
|---|---|
| Relief, Topography | : Undulating to gently undulating, with regular convex-concave slopes of up to 5%. |
| Vegetation; landuse | : Deciduous bushland of Acacia reficiens, Commiphora and Duosperma. Areas of Illaut, Laisamis, Korr almost devoid of vegetation |
| Soils | : Well drained shallow to moderately deep dark reddish brown gravelly sandy clay loam to sandy loam |
| Condition of topsoil and Erosion | : Over large areas in the surroundings of the permanent waterholes of Illaut, Laisamis and Korr, sheetwash erosion has removed the topsoil and part of the subsoil. The bare surface is characterised by a strong sealing that prevents a major part of the scant precipitation to infiltrate into the soil, and that forms a severe limitation to the restoration of the vegetation cover. |
| Accessibility for livestock | : No limitations |

Mapping unit 17: **UP**

| | |
|---|---|
| Surface area | : 4375 km2; 6.5% of total District area |
| Geology | : Mainly coarse pyroclastic rocks and volcanic conglomerates |
| Relief, Topography | : Very gently undulating to rolling topography, with short convex slopes. Dense network of V-shaped drainage lines |
| Vegetation; landuse | : Shrub vegetation mainly in drainage lines only. Elsewhere practically bare desert pavement, in places sparsely populated by annual grasses. |

| | |
|---|---|
| Soils | : Well drained moderately deep to shallow, brown, strongly calcareous very gravelly clay loam, with a desert pavement at the surface, and calcrete layers at shallow depths |
| Condition of topsoil | : The area is in very poor condition. Soils moisture storage is very low due to gravel content and shallow calcrete formation. Area of very low potential |
| Erosion hazard | : Water and wind erosion have hardly any impact due to the omnipresent gravelly surface layer |
| Accessibility for livestock | : The undulating topography is a moderate restriction |

Mapping unit 18: YP

| | |
|---|---|
| Surface area | : 1515 km2; 2.3% of total District area |
| Geology | : Alluvial deposits, largely derived from pyroclastic rock |
| Relief, Topography | : Almost flat, very gentle slopes at three levels of elevation, steeply dissected by many broad, flat-bottomed "laga's" |
| Vegetation; landuse | : Deciduous shrubland and sparse annual grassland. In laga's Acacia tortilis and Salvadora persica are common. Locally perennial grasses |
| Soils | : 1 (on undissected, almost flat to very gentle slopes) Moderately well drained, very deep, dark reddish brown gravelly clay loam, in places with an exceedingly gravelly or stony surface<br>2 (in the deeply entrenched broad "Laga's") Exceedingly gravelly soils of various drainage condition, depth, colour and texture; mainly strongly calcareous and saline, and frequent calcrete layers near to the surface |

| | |
|---|---|
| Erosion hazard | : In terms of geological erosion, the area is of a very unstable nature, whether "overutilized" or not |
| Accessibility for livestock | : Limited, due to the frequent steep banks between laga's and terrace remnants |

Mapping unit 19: **YV1**

| | |
|---|---|
| Surface area | : 724 km2; 1.1% of total District area |
| Geology | : Alluvium derived from volcanic rocks |
| Relief, Topography | : Almost flat to very gently sloping, locally gullied |
| Vegetation; landuse | : Various, mainly Acacia mellifera and A. reficiens bushland or bushed grassland |
| Soils | : Moderately well to imperfectly drained, very deep, reddish brown to grayish brown, calcareous, locally saline and sodic clay loam to cracking clay, in many places gravelly and/or with an exceedingly gravelly surface |
| Erosion hazard | : Strong wind erosion hazard whereever livestock is concentrated. In places gully development |
| Accessibility for livestock | : Occasional flooding may occur, which makes the area partly and temporary inaccessible. Also stickiness of the surface may restrict the accessibility in the rainy season |

Mapping unit 20: **YV2**

| | |
|---|---|
| Surface area | : 270 km2; 0.4% of total District area |

| | | |
|---|---|---|
| Geology | : | Colluviated and windblown deposits, mainly derived from pyroclastic rocks |
| Relief, Topography | : | Almost flat |
| Vegetation; landuse | : | Almost exclusively Indigofera sp. dwarf shrub |
| Soils | : | Well to somewhat excessively drained, moderately deep, yellowish brown, very friable, strongly calcareous fine gravelly loam to loamy sand |
| Condition of topsoil | : | Topsoils show low organic matter content, have a relative high infiltration capacity, so that run-off is limited to a minimum. No signs of sheet or gully erosion |
| Erosion hazard | : | The deposits being partly of a wind blown origin, are sensitive to wind erosion, when too frequently trampled by livestock |
| Accessibility for livestock | : | No restrictions |

Mapping unit 21: **YC**

| | | |
|---|---|---|
| Surface area | : | 956 km2; 1.4% of total District area |
| Geology | : | Alluvium derived from pyroclastic rocks and lake bed deposits, partly redeposited by wind erosion |
| Relief, Topography | : | Very gently undulating; slopes less than 2% |
| Vegetation; landuse | : | Pattern of bare- gravelly surface and Indigofera dwarfshrub; scattered Euphorbia cuneata, locally also Maerua crassifolia and Cadaba mirabilis |
| Soils | : | Complex of:<br>1 Well drained, deep, pale brown, strongly clacareous gravelly clay |

| | | |
|---|---|---|
| | | loam, with an exceedingly gravelly surface<br>2 Somewhat excessively drained, moderately deep, yellowish brown, strongly calcareous, saline, fine gravelly stratified sandy loam |
| Condition of topsoil | : | The first component is a degraded soil with desert pavement, devoid of vegetation.<br>The second component consists largely of mobile windblown deposits |
| Erosion hazard | : | Wind erosion is active in especially the second component. Here also, due to its topographic position, occasional run-on occurs, accompanied by sheet wash erosion. Fresh windblown deposits (small dune formations) are readily populated by Indigofera dwarf-shrubs |
| Accessibility for livestock | : | No restrictions; occassionally in wet season due to (very short lived) flooding |

Mapping unit 22: **PV1**

| | | |
|---|---|---|
| Surface area | : | 1865 km2; 2.8% of total District area |
| Geology | : | Basalt |
| Relief, Topography | : | Almost flat, slopes <2% |
| Vegetation; landuse | : | Deciduous bushland, alternating with perennial grassland (Lintonia nutans, Sorghum purpureum, Aspilia, Abutilon) |
| Soils | : | Imperfectly drained, very deep, dark brown, firm, calcareous cracking clay, locally stony |
| Condition of topsoil | : | Soils of relatively high production, fertility and organic matter content |

| | |
|---|---|
| Erosion hazard | : Soils, when under heavy grazing pressure, are sensitive to wind erosion.<br>Strong gully development hazard in neighbourhood of river system (mapping unit 34: VC), due to topography, sub-surface cracks and possible sodicity in deeper subsoil |
| Accessibility for livestock | : Limitations for cattle and camel in the wet season, due to stickyness of the clay soil |

Mapping unit 23: **PV2**

| | |
|---|---|
| Surface area | : 2395 km2; 3.6% of total District area |
| Geology | : Basalt |
| Relief, Topography | : General slope is almost flat. Irregular mesotopography due to many low rock outcrop ridges (Laharflow morphology) |
| Vegetation; landuse | : Bushed grassland |
| Soils | : Probably similar to those of unit PV1, only with rock outcrops and surface stoniness |
| Erosion hazard | : Probably low sheet and gully erosion hazard due to topography |
| Accessibility for livestock | : Moderate restrictions for cattle due to rock outcrops |

Mapping unit 24: **PsU1**

| | |
|---|---|
| Surface area | : 528 km2; 0.8% of total District area |
| Geology | : "Red Sandy Plain" deposits. Tertiary sediments of Basement System origin |
| Relief, Topography | : Sedimentary plain, very gently undulating, slopes <2% |

| | | |
|---|---|---|
| Vegetation; landuse | : | Bushland |
| Soils | : | Well drained very deep, dark red, sandy clay loam to sandy loam |
| Condition of topsoil | : | Rather low in organic matter content, but relatively high infiltration capacity, due to porous and well structured soil. Risk of top soil sealing in heavily utilized areas |
| Erosion hazard | : | Low erosion hazard, due to almost flat topography |
| Accessibility for livestock | : | No limitations except locally due to dense bush |

Mapping unit 25: PsU2

| | | |
|---|---|---|
| Surface area | : | 2500 km2; 3.7% of total District area |
| Geology | : | Undifferentiated sediments, mainly from Basement System rocks |
| Relief, Topography | : | Almost flat topography, slopes <2% |
| Vegetation; landuse | : | Partly dense bushland, and bushed grassland. Species composition dependent on drainage condition and salinity. |
| Soils | : | Complex of among others:<br>1 Moderately well drained, very deep, dark brown soils of varying texture and consistence<br>2 Imperfectly drained shallow, grayish brown, very firm sodic sandy clay |
| Condition of topsoil | : | Widely varied: locally rich in organic matter (component 1) locally strongly sealed (component 2); also in places cracking clay with thick, loose, dusty surface layer |

Erosion hazard : Low in soil component 1; high sheeterosion hazard at strongly sealed surfaces. Wind erosion hazard on cracking clay soils with loose surface layer

Accessibility for livestock : Mainly restricted due to dense bush, and in wet season due to local flooding

Mapping unit 26: **PsU3**

Surface area : 2590 km2; 3.9% of total District area

Geology : Undifferentiated sediments, derived mainly from Basement System rocks

Relief, Topography : Very gently undulating plains; overall slopes less than 2%. In many places with undulating mesotopography, caused by numerous shallow drainage lines and/or subrecent dune formation

Vegetation; landuse : Bushed grassland and Bushland with Duosperma and Indigofera dwarf shrub understory.

Soils : Association of:
(1) The elevated parts of the gently undulating mesorelief:
- Somewhat excessively drained, very deep, reddish brown loamy sand
(2) The depressional areas between the sub recent dunes:
- Moderately well drained, very deep, brown, calcareous sandy clay loam, locally saline and sodic, sealed

Condition of soil and erosion hazard:
In the neighbourhood of Illaut, Korr and Laisamis the stabilized dunes have been reactivated due to over utilization of the rangeland.
Elsewhere the "dune component" has a good infiltration capacity and bears at least a reasonable cover of vegetation (Indigofera and

Blepharis a.o.). The depressions are mainly affected by sealing, low infiltration rates and hence and sheet erosion

Accessibility for livestock : Only due to locally dense bush there may be some restrictions for cattle and camels

Mapping unit 27: **PsU4**

Surface area : 4500 km2; 6.7% of total District area

Geology : Undifferentiated alluvial sediments, largely derived from Basement System rocks

Relief, Topography : Almost flat extensive plains, with gently undulating mesorelief, due to numerous shallow drainage lines and subrecent dune formation

Vegetation; landuse : Bushland and bushed grassland

Soils : Association of:
(1) at the relatively elevated parts (subrecent dunes):
- Somewhat excessively drained, very deep, dark reddish brown, soft to loose calcareous sand to sandy loam.
(2) In the depressional areas:
- Imperfectly drained, very deep, dark reddish brown to brown firm, sodic, calcareous and saline sandy clay loam, in many places with a soft sandy loam top soil

Condition and erosion hazard:

The higher parts (component 1) are sensitive to wind erosion. The vegetation cover is easily damaged by trampling of the surface. In the depressions (component 2) either the soil is strongly sealed (degraded and sheet-washed until natric-B horizon) and/or covered by wind deposists deflated from the subrecent dunes. This process is strongly represented in the heavily damaged areas between

| | |
|---|---|
| | Kargi, Korr, Illaut, Laisamis and Loglogo. The loose surface material is however readily (a time-span of several years) re-occupied by Indigofera and/or other dwarf shrubs, and may stabilise after a number of seasons |
| Accessibility for livestock : | The lower parts are locally temporarily inaccessible due to flooding during the wet season |

Mapping unit 28: Pl1

| | |
|---|---|
| Surface area : | 400 km2; 0.6% of total District area |
| Geology : | Lake bed deposits, derived from various parent rock |
| Relief, Topography : | Almost flat and very gently undulating topography |
| Vegetation; landuse : | Indigofera dwarf shrub |
| Soils : | Well drained, very deep, pale brown, very friable, strongly calcareous, saline, fine gravelly stratified sandy loam |

Topsoil condition and erosion hazard:

The surface soil is very low in organic matter content, but due to texture and consistency, has a fairly high infiltration capacity.
The topsoil is unstable in respect to wind action; deflation and accumulation of soil material seems a continuous process.
The area is sensitive to overutilization however: deflation can easily lead to the formation of unproductive desert pavements.

| | |
|---|---|
| Accessibility for livestock : | no restrictions |

Mapping unit 29: **Pl2**

| | |
|---|---|
| Surface area | : 495 km2; 0.7% of the total District area |

As unit 28, but with frequent table-land-like calcrete outcrops. Formerly common Acacia tortilis woodland, of which nowadays some scattered remnants are left.

Mapping unit 30: **Pl3**

| | |
|---|---|
| Surface area | : 1225 km2; 1.8% of total District area |
| Geology | : Lake bed deposits, from various sources |
| Relief, Topography | : Flat to almost flat floor of former lake, presently forming the Chalbi desert |
| Vegetation; landuse | : Nil |
| Soils | : Imperfectly to poorly drained, very deep, brown to olive grey, strongly clacareous, strongly saline and sodic soils of varying, mostly fine, textures |
| Condition | : Seasonally flooded, highly saline soil with extensive salt crusts at surface. The area is of no value to rangeland use, except as source of mineral salts |

Mapping unit 31: **PlX**

| | |
|---|---|
| Surface area | : 1695 km2; 2.5% of total District area |
| Geology | : Sandy and calcareous lake bed (?) sediments derived from various sources, mainly non- volcanic (a.o. Turkana grits?). |

Relief, Topography : Very gentle to almost flat terrace remnants at three main topographic levels, separated by rather extensive badland topography, i.e. intricately dissected, very steep, short slopes

Vegetation; landuse : bushland and bushed grassland

Soils : (1) at terrace remnants:
- Somewhat excessively drained, deep, pale brown, friable, calcareous loamy sand (high and middle level)
- Well to imperfectly drained, very deep, pale brown, friable and loose, calcareous and saline stratified soils of mostly coarse sandy textures (lowest level)
(2) in badland topography:
- excessively drained sandy soils of varying depth

Condition of topsoil and erosion hazard:
At the terrace remnants the soils have a high infiltration rate due to coarse sandy textures and a low erosion hazard. However on the lowest level of the terrace remnants the soils are sensitive to wind erosion. The badland topography is considered a result of sub-recent geomorphic processes, and not due to man-induced accelerated erosion

Accessibility for livestock : The lowest level of the terraces is in the wet season temporary and locally inaccessible due to flooding. The badlands are inaccessible

Mapping unit 32: **AA**

Surface area : 1165 km2; 1.7% of the total District area

Geology : Undifferentiated, predominantly recent alluvial deposits

Relief, Topography : Almost flat, <1%

Vegetation; landuse : Locally perennial grassland; locally woodland and bushland of Acacia seyal

Soils : Seasonally flooded, imperfectly drained, very deep, firm, dark reddish brown, calcareous, cracking clay, or stratified sandy clay loam to sandy loam, locally saline and sodic

Condition of topsoil and erosion hazard:
The area is a productive one, mainly due to the seasonal floodwaters that it may receive. Locally the situation is taken advantage of by the cultivation of sorghum. Perennial grassland is not uncommon. In prolonged drought periods the soils develop a thick loose layer over a hard, deeply cracking subsoil. Along stream courses a network of gullies tend to develop during the periods of flooding (streambank erosion) , with the sub-surface cracks as a starting point

Accessibility for livestock : In the wet season the accessibility may be severely limited due to flooding and/or sticky and muddy soil consistence. Locally also dense Acacia bush poses restrictions.

Mapping unit 33: BV

Surface area : 595 km2; 0.9% of total District area

Geology : Sediments derived from undifferentiated volcanic rocks, including pyroclastics and ashes

Relief, Topography : Almost flat to very gently sloping

Vegetation : Mainly dwarf shrubland of Indigofera with sparsely scattered Acacia reficiens, Euphorbia cuneata

Soils : Well drained, deep, very friable, yellowish brown strongly calcareous, fine gravelly sandy loam, locally with calcrete gravel or - layers at shallow depth

Condition of topsoil : Rather good to moderate infiltratiqn rates, although also signs of runoff at lower slope parts and valley centre have been observed

Erosion hazard : Low sheet erosion hazard; no gully development; moderate wind erosion hazard

Accessibility for livestock : No restrictions

Mapping unit 34: VC

Surface area : 1386 km2; 2.1% of total District area

Geology : Partly basalts, and alluvium derived from various rocks

Relief, Topography : Valley complex of riverine plateau incision and areas of badland topography associated with these

Vegetation; landuse : Various. Dense bushland and annual grassland

Soils : Complex of various, mainly bouldery, dark clay soil

Condition of topsoil and erosion hazard: Instable area, largely badly eroded and being eroded, probably due to overutilization (north of Turbi; Ethiopian border).

Accessibility for livestock : The badland areas and valley incisions are of low accessibility, also due to the dense bushland

Mapping unit 35: **DX**

| | |
|---|---|
| Surface area | : 615 km2; 0.9% of total District area |
| Geology | : Windblown sands and sandy loams of various origin |
| Relief, Topography | : Dunes; rolling mesotopography of short convex slopes |
| Vegetation | : Euphorbia cuneata over Indigofera dwarf shrubland |
| Soils | : Association of:<br>1 on the dunes :<br>- Excessively drained, very deep, reddish yellow, very friable calcareous and sodic sand<br>2 in between the dunes :<br>- poorly drained, very deep (locally shallow), dark brown, firm, calcareous saline and sodic, sandy clay loam with locally calcrete gravel or - layers at shallow depth |
| Erosion hazard | : The dunes are very sensitive to overutilization, so that "reactivation" of these dunes takes place under moderate grazing pressure. Recuperation of the vegetation (regrowth of Indigofera) is a relatively quick process. |
| Accessibility for livestock | : No restrictions for camel and goats; slight restrictions for cattle |

Mapping unit 36: **La**

| | |
|---|---|
| Surface area | : 5625 km2; 8.4% of total District area |
| Geology | : Basalt flows of recent and subrecent origin |
| Relief, Topography | : Overall landform almost flat, but rugged meso topography of numerous ridges of rock outcrops, with pockets of soil in between |

| | | |
|---|---|---|
| Vegetation | : | Mainly bushland and annual grasses |
| Soils | : | Extremely rocky, bouldery and stony area with a restricted amount of well drained clay to clay loam soils of varying depth |
| Accessibility for livestock | : | The area is virtually inaccessible for livestock |

# 5 SOIL PROPERTIES OF RELEVANCE TO THE QUALITY OF RANGELAND

This chapter will deal with soil properties that influence the performance of rangeland. Firstly those characteristics will be presented that determine the primary production of forage and browse (Water availability, effective surface area, fertility); Secondly those that are of importance to management aspects of rangeland, like accessibility and erosion hazard.

## 5.1 Water availability

The availability of moisture for the growth of natural vegetation and agricultural crops is dependent on rainfall, evaporation, moisture storage capacity of the soil, eventual salinity, and (very important in arid/semi-arid areas) the infiltration capacity of the surface soil.

We will use the term Water Holding Capacity here for the combined effect of three main <u>soil</u> characteristics concerned, i.e. rooting space, available water capacity (AWC) and infiltration capacity of the soil surface.
The AWC is expressed in mm water per m soil, and depends on a number of physical soil properties that will not be dealt with here, as collection of these data was not possible in the context of this survey work. As a rule of thumb, however, the order of magnitude of AWC is related to the soil texture. Approximate values are given below for homogeneous soils of one meter deep, that have no stones, boulders, gravel or hardpans of any kind. (After Bookers Soil Manual):

High AWC : >180 mm.m$^{-1}$ very fine sandy and silty textures
Moderate AWC: 120-180 mm.m$^{-1}$ clayey soils, sandy, silty clay loams, sandy loams
Low AWC : <120 mm.m$^{-1}$ Sands, loamy sands, coarse sandy loams.

An estimation ("rating") for the AWC of all units is given in table 1. This rated performance of AWC according to texture receives an "upgrading" in case of high organic matter content in the soil.
The depth of the soil, from surface to rock or impenetrable layer, together with the volume of coarse fragments, as stones, boulders, gravel, determines the rooting space. Soils are considered deep and very deep when they have a depth of over 80 cm. Moderately deep soils are between 40 and 80 cm deep; shallow soils 20-40 cm, and very shallow soils less than 20 cm. The ratings for effective soil depth are given in table 1, and range from 1: Very deep to 4: very shallow.

The amount of moisture in the soil is not only dependent on the amount of rain, AWC and rooting space. Of crucial importance, especially in arid and semi-arid conditions, is the infiltration capacity of the surface soil. Infiltration determines what percentage of the already scarce rainfall actually penetrates into the soil and becomes available to plant growth. No measurements of infiltration capacity have been made, as this was not feasible in the context of the present study (Infiltration tests are time consuming, logistically difficult, and reliable only if many replica's are made). It is sufficiently known from other areas in Kenya how one can expect the surface soil to behave in heavy showers of short duration. It is also predictable from surface features whether high or low infiltration rates are likely. In this context soil degradation plays an important role, i.e. the status of over-utilization of the rangeland, and consequently its top soil conditions, (organic matter content; structure) and basal cover of vegetation.

For soils developed on Basement System Rocks and derived sediments the degree of top soil sealing is an adequate parameter or "quick look method" for estimating infiltration: A strongly sealed surface hardly allows any rainwater to enter the soil. Soils developed on volcanic ashes or soils with volcanic ash admixture usually have high infiltration rates. Also, generally speaking, better infiltration rates are found on well vegetated areas, i.e. those with higher rainfall, vegetation and organic matter in the topsoil.

An estimation for all units is given in table 1, where 1 denominates high infiltration; 2 moderate, and 3 low rates.

Results of these three components of water holding capacity and a final classification is given in table 1.

The final ratings range from 1: very high soil water holding capacity to 5: very low.

A good performance in respect of water availability (apart from climate) is offered by mountains and hills on volcanic and pyroclastic rocks; high-level volcanic foot-ridges: the almost flat volcanic plateaus; plains and piedmont plains; the high lying component (windblown deposits) of sedimentary areas (mapping units 1 and 2: MV; 4 and 5: HP; 7: FrV1; 13: LV1 ; 15 : LV3 ; 20: YV2; 22 : PV1 ; 25: PsU2; 26: PsU3; 27: PsU4) .

A poor performance offer the basement system and volcanic hills, the step faulted volcanic plateaus; the uplands in basement system rocks and on pyroclastic rocks; the more recent lavaflows and the low lying components of various sedimentary areas (mapping units 3: HU; 6: HV; 14: LV2; 16: UU; 17: UP; 23: PV2; 25: PsU2; 26: PsU3; 27: PsU4; 36: La).

Fig. 3 give the distribution of three levels of soil productive capacity, not considering climate type.

Table 1 Ratings of primary producion related soil factors*.

| Unit no. | Mapping unit symbol | Effective soil depth | Available water capacity | Infiltration capacity | Final rating water holding capacity | Effective surface area |
|---|---|---|---|---|---|---|
| 1 | MV1 | 1(3) | 1 | 1 | 1 | 1-2 |
| 2 | MV2 | 1 | 1 | 1 | 1 | 1 |
| 3 | HU | 3 | 3 | 2 | 4 | 3-4 |
| 4 | HP1 | 2 | 1 | 1 | 2 | 2 |
| 5 | HP2 | 2 | 2 | 1 | 2 | 2-3 |
| 6 | HV | 3 | 3 | 2 | 4 | 4 |
| 7 | FrV1 | 2-3 | 1 | 2 | 2 | 3 |
| 8 | FrV2 | 2-3 | 2-1 | 3 | 3 | 3 |
| 9 | FrV3 | 2-3 | 2 | 2-3 | 3 | 3(4) |
| 10 | FU | 1 | 2-3 | 2 | 2-3 | 1 |
| 11 | FP | 2-3 | 2-3 | 2 | 3 | 2 |
| 12 | FV | 1-2 | 2 | 2-3 | 3 | 2-3 |
| 13 | LV1 | 1 | 2 | 2 | 2 | 2(4) |
| 14 | LV2 | 3-2 | 2 | 2 | 4 | 4 |
| 15 | LV3 | 1 | 2 | 2 | 2 | 2(4) |
| 16 | UU | 3-2 | 2-3 | 3 | 4 | 1 |
| 17 | UP | 2-3 | 3 | 3 | 5 | 5(4) |
| 18 | YP | 3 | 2-3 | 2-3 | 4 | 4 |
| 19 | YV1 | 1 | 2 | 2-3 | 3 | 3 |
| 20 | YV2 | 2 | 1-2 | 1 | 2 | 1 |
| 21 | YC | 2/2 | 2/1 | 2/1 | 3/3 | 5/1 |
| 22 | PV1 | 1 | 2 | 2 | 2 | 1-2 |
| 23 | PV2 | 1/4 | 2 | 2/3 | 2/5 | 3-4 |
| 24 | PsU1 | 1 | 1-2 | 1-2 | 2 | 1 |
| 25 | PsU2 | 1/3 | 2/2 | 2/4 | 2/5 | 1 |
| 26 | PsU3 | 1 | 3/2 | 1/3 | 2/3 | 1 |
| 27 | PsU4 | 1/3 | 3/2 | 1/4 | 2/5 | 1 |
| 28 | P11 | 2 | 2 | 2 | 3 | 1 |
| 29 | P12 | 3-2 | 2 | 2 | 3-4 | 1(4) |
| 30 | P13 | 4 | 1-2 | 3-2 | 2/5 | 1 |
| 31 | P1X | 1/3 | 3/2 | 1/3 | 5 | 1 |
| 32 | AA | 1 | 2-1 | 2 | 2 | 1 |
| 33 | BV | 1-2 | 2 | 2 | 2-3 | 1 |
| 34 | VC | 2(?) | 2(?) | 2(?) | 3(?) | 2(?) |
| 35 | DX | 1/3 | 3/2 | 1/3 | 2/4 | 1 |
| 36 | La | 4(1) | 2 | 2 | 5(2) | 5 |

See para. 5.1 and 5.2. See also Fig. 3.

* Figures, separated by ../.., give respective ratings for high and low components of the mapping unit.

1: good, favourable, high; 5: bad, unfavourable, low.

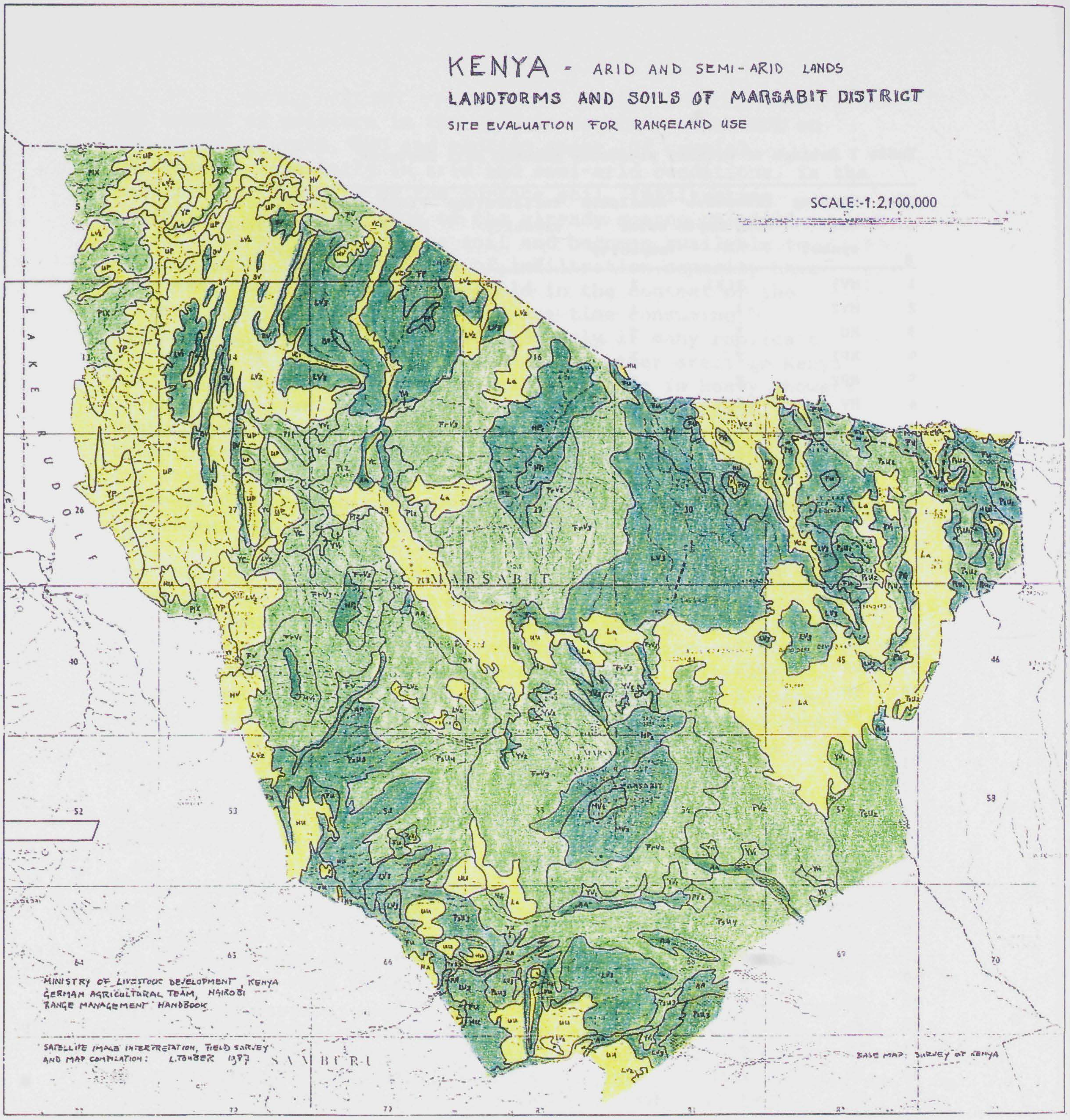


fig 3. SOIL PRODUCTIVE CAPACITY - NOT CONSIDERING CLIMATE TYPE

DISTRIBUTION OF MAP UNIT RATINGS

HIGH

MODERATE

LOW

5.2 Effective surface area

Stones, gravel and boulders on the soil surface pose a reduction of the effective surface area. A good, productive soil that is covered for 40% by stones for example, is only covered by vegetation for the remaining 60%, so only 60% of the units surface area can be considered as grazing area.

Table 1, last column, gives the estimated "effective grazing surface percentage" in classes; 1 means over 80%; 2: 60-80%; 3: 40-60%; 4: 20-40% and 5 means less than 20% effective surface area. This component is included in the final rating of the productive capacity of the soil as expressed in fig. 3.

5.3 Nutrient availability, toxicity

Fertility of the soil is in agricultural production important, and equally in rangelands a fertile soil tends to produce more vegetation than a soil with nutrient deficiencies. However, it has been argued that in areas of less than 500 mm of rainfall per year the soil fertility is not an important limitation to productivity of range lands.

It has been observed in this study that in general the soils in Marsabit District, being under semiarid to arid climate, show high amounts of calcium, that the pH ranges from 7,0 to 8,5, and that the soils are not likely to be deficient in P and K.

Of these dry areas the topsoils are very low in organic carbon however (<0.5%) and probably also in Nitrogen (not determined).

The tentative conclusion is that natural fertility is not a major limiting factor in the rangelands of Marsabit District.

Salinity reaches toxic levels in a number of places, such as the Chalbi Desert (mapping unit 30: Pl3) and locally in alluvial deposits of mapping units 29: Pl2; 33: BV, 32: AA and 19: YV1, where the soil is practically devoid of vegetation.

It is not known whether sodicity reaches toxic levels in Marsabit District. High sodicity is found in most sedimentary plains, mapping units 25: PsU2 (partly) and 27: PsU4 (lower level). This has an adverse effect on soil structure, infiltration and erodibility, rather than a direct influence on plant growth.

## 5.4 Erosion Hazard

Soils influence the production of rangelands indirectly by their resistance or sensibility to overgrazing.

Areas from where more vegetation is grazed (removed) than yearly is produced, the vegetation cover changes its composition, tends to diminish and disappear gradually. When the cover of natural vegetation disappears, soil degradation of some form is sure to take place, the most well known being soil erosion.

It depends on the type of soil how this degeneration will proceed, and in what form, and to what extent the degrading soil has a capacity to allow the vegetation cover to recuperate when grazing pressure is relieved.

The removal of vegetation and exposure of bare soil to the atmosphere has an adverse effect through a change in soil temperature regime: the humus of the top soil tends to disappear (oxidation) , while the impact of raindrops and treading of livestock is much stronger on the bare soil surface. The result is a surface layer of structureless soil particles that have either a loose (very : "friable" or "fluffy") or a highly compacted concrete-like (soil "sealing") character. The former, loose, very dusty, degraded soil surface is common on soils of volcanic origin (especially ashes or ash-enriched soils) or on sediments derived from volcanics. The latter, sealed surface, commonly develop on soils derived from Basement System rocks.

The three main forms of erosion: sheet, gully and wind erosion are active in Marsabit District. The term sheet erosion is a widely used term referring to the result of rill or rill wash erosion meaning that surface soil is removed sheet-wise by run off water over large tracts of land. This in contrast to the situation indicated by gully erosion where run off water is concentrated in narrow channels or gullies. It is often implied that gully erosion is an advanced stage in deterioration, following the stage of sheet erosion.
Both forms of erosion occur in Marsabit on rather different soils however.
Wind erosion is the removal of loosened soil particles by wind action, a feature also strongly represented in Marsabit District.

Forms of erosion and possibilities for recuperation:

**Sheet erosion**

A common feature on overutilized soils of Basement System areas (all -U units) is sheet erosion in various stages of progress. This is associated with a lesser or stronger sealing of the surface, ie a hard and compacted soil surface, that has a strong negative influence on the possibilites for the recuperation of the vegetative cover. A strongly sealed surface causes a low infiltration rate and high percentage of already scarce rainwater to run off. The hard surface is a strong limitation for seeds to germinate and creepers (stolons) to root. Reseeding, if ever planned, will fail if these soils are not plowed in advance - in the context of extensive rangeland use a too costly exercise. Strong forms of sheet erosion and sealing are observed at mapping unit 16: UU between Illaut and Korr. Recuperation of the natural vegetation will take probably a period of time in the order of magnitude of 10-20 years. Less severe forms of sheet erosion and surface sealing are locally observed in mapping unit 10: FU, and also rather widespread in the low-lying component of the sedimentary plains (mapping units 26: PsU3 and 27: PsU4).

**Gully erosion**

Sealing of the surface soil is usually not, or to a far lesser extent, observed on soils in the volcanic areas. In the for Marsabit District higher rainfall areas, on the volcanic slopes of Marsabit, Hurri and Kulal, some gully erosion is observed (not meaning the gullies in mapping units 7: FrV1 and 8: FrV2, as those ravine-like drainage lines are considered results of a natural geological/morphological process). Subsurface cracks in the mainly clayey soils in volcanic areas are thought to be the starting point for gully development, and also for the rather common "sinkholes", "tunnelerosion" or "piping" that occur also in the drier volcanic regions. On some sloping areas of the mentioned hill masses (especially Hurri Hills), gullies have been observed that are nowadays completely recovered by grass vegetation. The rather favourable physical and chemical properties of these red clays are apparently allowing a rather fast recuperation of the natural vegetation on a bare surface of this soil type. Yet the development of erosion gullies, especially on the grazing areas of the Hurri hills, Marsabit, Kulal and Asie are a cause for concern, as these areas are classified as high potential (cattle) grazing areas, a comparative rare feature representing a good deal of the total production of the District.

A serious form of accelerated gully development is observed north of Turbi (mapping unit 34: VC) in dark coloured cracking clay soils, that probably are sodic (unstable clays) in the deeper subsoil.
An altogether different type of erosion gullies are the activated lines of drainage in the footslopes (mapping unit 10: FU) of the Basement System Hills (e.g. Ndoto Mountains). This gully development is not so much the result of over grazing on the footslopes itself, but rather due to removal of protective vegetation in the hills, causing a different hydrological regime in the catchment region above the footslopes.

The badland topography of mapping unit 31: PlX is considered (like the ravines of units FrV1, FrV2), the result of a recent geomorphological condition rather than man-induced erosion.

**Wind erosion and deposition**

A less conspicuous, but widespread feature is wind erosion, especially in the dry volcanic areas and on the sedimentary plains. It is largely the trampling of livestock that loosenes the soil surface particles, which are picked up by the constantly strong and dry southwesterly wind.

Soils that are sensitive in this respect are those that have developed on the volcanic ash deposits and/or that are ash-enriched (mapping units 17: UP; 21: YC; 18: YP; 11: FP; 20: YV2; 28: Pl1; 29: Pl2; 30: Pl3 and locally 9: FrV3; 14: LV2 and 15: LV3). Also prone to wind erosion are those soils that exist of subrecent windblown deposits such as dune formations (mapping units 35: DX, high level component of mapping units 26: PsU3 and 27: PsU4).

The ultimate stage of wind erosion in many areas of volcanic origin is the so-called desert pavement, ie areas where the surface is covered by a residually enriched layer of gravel. Unit UP and parts of YC are notorious in this respect; the only vegetation left being some shrubs in the lines of drainage. Also the areas around Balesa (mapping unit 15: LV3), Kalacha and Maikona (mapping unit 9: FrV3) show the same kind of deterioration. Obviously the restoration of a vegetation cover in areas with a top soil that exists of pure gravel, will be a long term process.
Wind erosion on areas that exist of originally windblown material forms a less conspicuously dramatic rangeland deterioration, while a positive aspect in these areas is the fact that the windblown material is redeposited in a not too distant neighbourhood. These recent windblown deposits (especially in mapping unit 27: PsU4) have one favourable characteristic, which is a high infiltration capacity for rain and apparently are readily repopulated by Indigofera spinosa dwarf shrubs. (mapping units 26: PsU3; 27: PsU4; 35: DX; 28: Pl1; 29: Pl2 and 21: YC).

**Actual and potential erosion**

On the map legend a column is reserved for "Erosion hazard after removal of vegetation". The actual erosion or top soil degradation is not evenly distributed over the various soil mapping units, but mainly concentrated around permanent water holes. This actual situation is not expressed in the map legend under the column erosion hazard. The legend indicates only a comparison between units in the respect of sensitivity to erosion that will take place if the area is under too high grazing pressure.

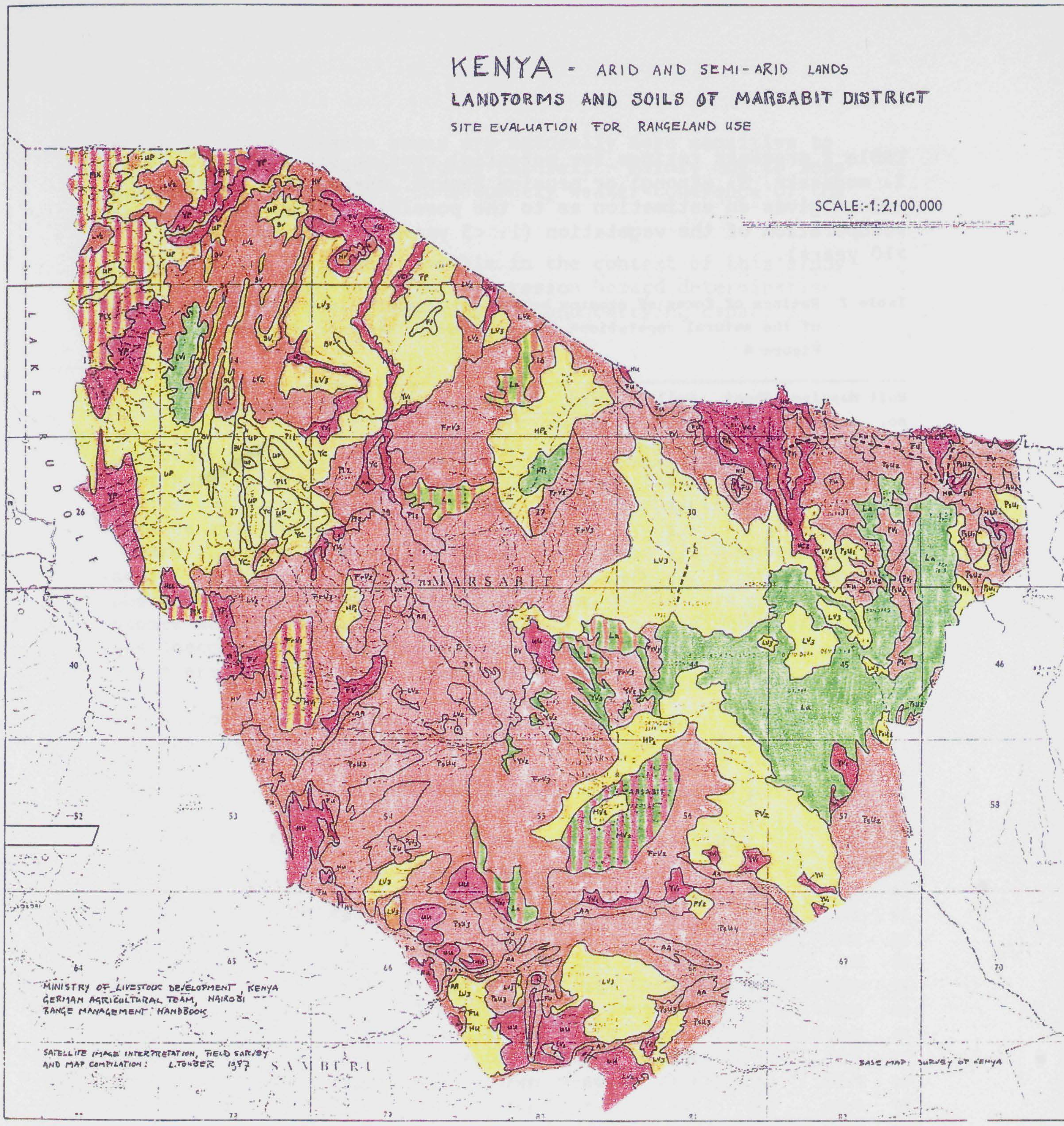


fig.4 **EROSION HAZARD**

DISTRIBUTION OF MAP UNIT RATINGS - SEE TABLE 2

- NON - SLIGHTLY SENSITIVE
- SLIGHTLY - MODERATELY SENSITIVE
- MODERATELY - HIGHLY SENSITIVE
- HIGHLY SENSITIVE

Table 2 presents ratings for potential erosion (1: slight, 2: moderate, 3: strong) or erosion hazard, whereby the fourth column gives an estimation as to the possibility for the recuperation of the vegetation (1: <5 years, 2:5-10 years, 3: >10 years).

Table 2 Ratings of forms of erosion hazard and possibilities for recuperation of the natural vegetation*. For explanation see Para. 5.4. See also Figure 4.

| Unit no. | Mapping unit symbol | Sheet erosion hazard | Gully erosion hazard | Wind erosion hazard | Possibilities for recuperation | Final rating |
|---|---|---|---|---|---|---|
| 1 | MV1 | 1 | 2-3 | 1 | 1 | 2-4 |
| 2 | MV2 | 1 | 1-3 | 2 | 1 | 1-4 |
| 3 | HU | 3 | 3 | 1 | 3 | 4 |
| 4 | HP1 | 1 | 1 | 1-2 | 1 | 1 |
| 5 | HP2 | 1 | 2 | 2 | 1 | 2 |
| 6 | HV | 2 | 2 | 2 | 2 | 3 |
| 7 | FrV1 | 1 | 3 | 1 | 1-3 | 2-4 |
| s | FrV2 | 1 | 3 | 1-2 | 2 | 3-4 |
| 9 | FrV3 | 1 | 2 | 2-3 | 2 | 3 |
| 10 | FU | 3 | 2 | 1 | 2 | 3 |
| 11 | FP | 2 | 1 | 2 | 2 | 2 |
| 12 | FV | 2 | 3 | 2 | 2 | 4 |
| 13 | LV1 | 1 | 1 | 2 | 1 | 1 |
| 14 | LV2 | 1 | 2-3 | 2 | 2 | 3 |
| 15 | LV3 | 1 | 2 | 2 | 2 | 2 |
| 16 | UU | 3 | 2 | 2 | 3 | 4 |
| 17 | UP | 1 | 1 | 2 | 3 | 2 |
| 18 | YP | 2 | 2 | 3 | 2 | 4 |
| 19 | YV1 | 2 | 2 | 3 | 2 | 4 |
| 20 | YV2 | 1 | 1 | 2 | 1 | 1 |
| 21 | YC | 1/1 | 1/1 | 2/3 | 3/2 | 2/2 |
| 22 | PV1 | 1 | 2-3 | 2 | 2 | 3 |
| 23 | PV2 | 1 | 1 | 2 | 2 | 2 |
| 24 | PsU1 | 2 | 1 | 1 | 2 | 2 |
| 25 | PsU2 | 1/3 | 2/2 | 3/2 | 2/3 | 3/4 |
| 26 | PsU3 | 1/3 | 1/1 | 3/2 | 1/3 | 2/4 |
| 27 | PsU4 | 1/3 | 1/1 | 3/2 | 1/3 | 2/4 |
| 28 | P11 | 1-2 | 1 | 3 | 2 | 2-3 |
| 29 | P12 | 2 | 1 | 3 | 2 | 3 |
| 30 | P13 | 1 | 1 | 2 | 3 | 2 |
| 31 | P1X | 1/2 | 1/3 | 2/1 | 1/3 | 2/4 |
| 32 | AA | 1 | 2-3 | 2 | 2 | 3 |
| 33 | BV | 1 | 1 | 2 | 1 | 2 |
| 34 | VC | 2 | 3 | 3 | 2 | 4 |
| 35 | DX | 1/1 | 1/1 | 3/2 | 1/3 | 2/3 |
| S6 | La | 1 | 1 | 1 | 1 | 1 |

* Figures separated by ../.. indicate respective ratings for high and low components of mapping units. Figures connected by hyphen indicate a range of ratings.

A fifth column gives the final ratings for sensitivity to erosion/degradation hazard, ranging from 1: slightly sensitive to 4: highly sensitive. Distribution of these final ratings are presented in fig. 4.

Areas in drier climate zones are naturally more sensitive to erosion than in areas of higher rainfall - mainly due to less natural vegetation and a consequently weaker coherence of the top soil structure.

Unfortunately it is not possible in the context of this study to reach to a more quantitative erosion hazard determination for the purpose of range evaluation and carrying capacity.

## 5.5 Constraints to the accessibility for livestock

Livestock has to travel daily, or almost daily, between boma, grazing area and watering point. The larger this action radius (with mostly the watering point as focus) the more pasture available.

Where the easy progress of the daily movement is hampered, the action radius, and thus grazing area, is reduced. A notorious obstacle in this respect, especially for cattle, are surface stones and boulders. In the wet season not only flooded areas are inaccessible, but also muddiness or stickiness of clay soils are, temporarily, a constraint.

The following land characteristics have been taken into account for the evaluation of accessibility for livestock (see table 3):

Stoniness-rockiness at the surface (1: no stones; 3: very rocky);

Steepness of the terrain (1: flat, gently indulating; 3: steep);

Flooding, ponding )<br>
Stickiness, muddiness ) in wet season only ( - : no additional constraints; 5: inaccessible)

Especially goats are more adapted to rough terrain conditions, and can reach areas that are otherwise inaccessible to cattle. Camels are assumed to take an intermediate position in this respect. Table 3 gives ratings of the land for goats, camels and cattle separately, for permanent, year round conditions.

Rating 1 stands for "no restrictions" and 5 for "virtually inaccessible".

Ratings indicated between brackets for additonal wet season constraints reflect only situations in years of "above average" rainfall.

Fig. 5 and 6 give the distribution of these map unit ratings.

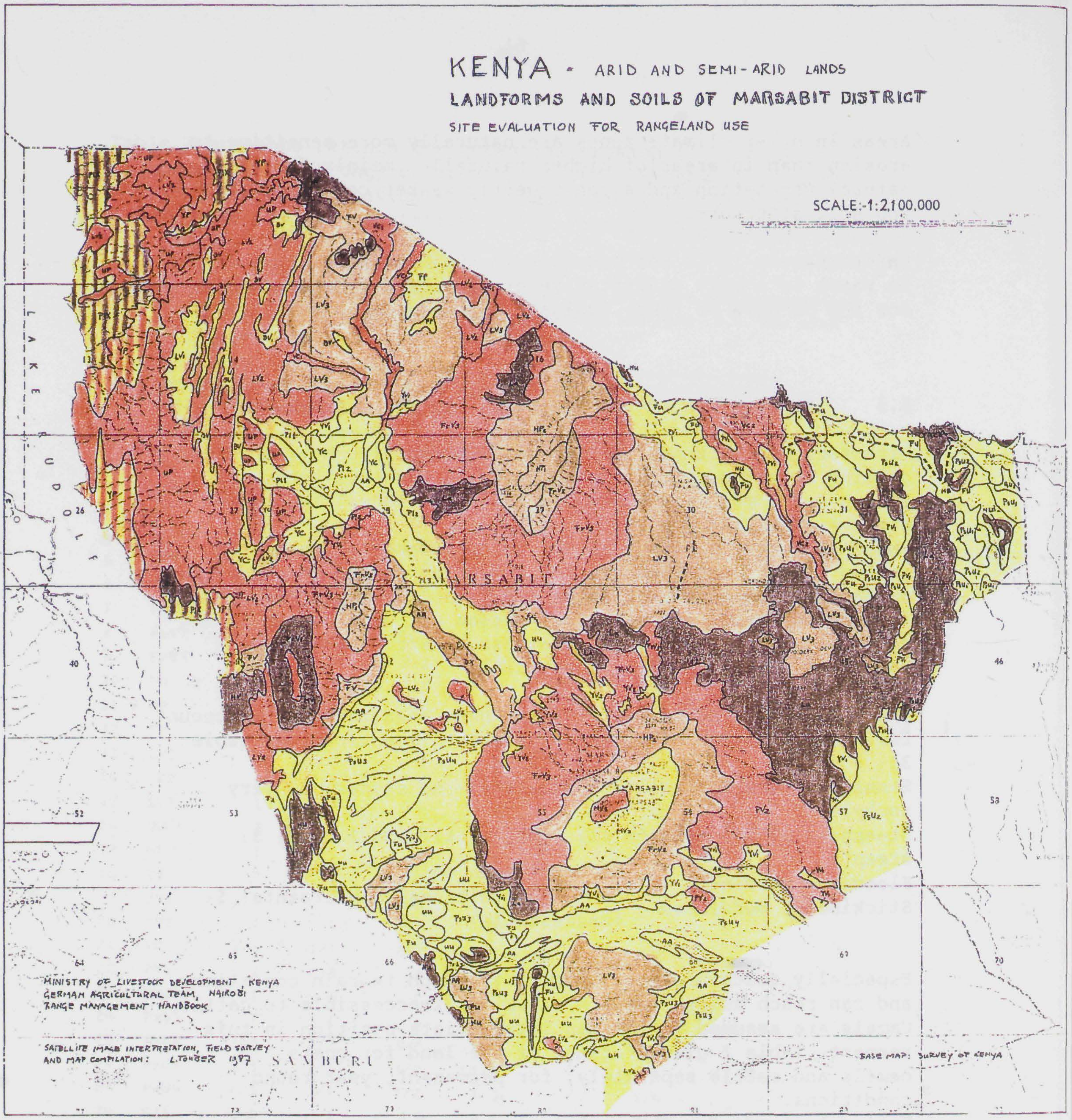


fig. 5 LIMITATIONS TO ACCESSIBILITY: YEAR-ROUND CONSTRAINTS

DISTRIBUTION OF MAP UNIT RATINGS - SEE TABLE 3

NO LIMITATIONS

SLIGHT LIMITATIONS

MODERATE LIMITATIONS

SEVERE LIMITATIONS

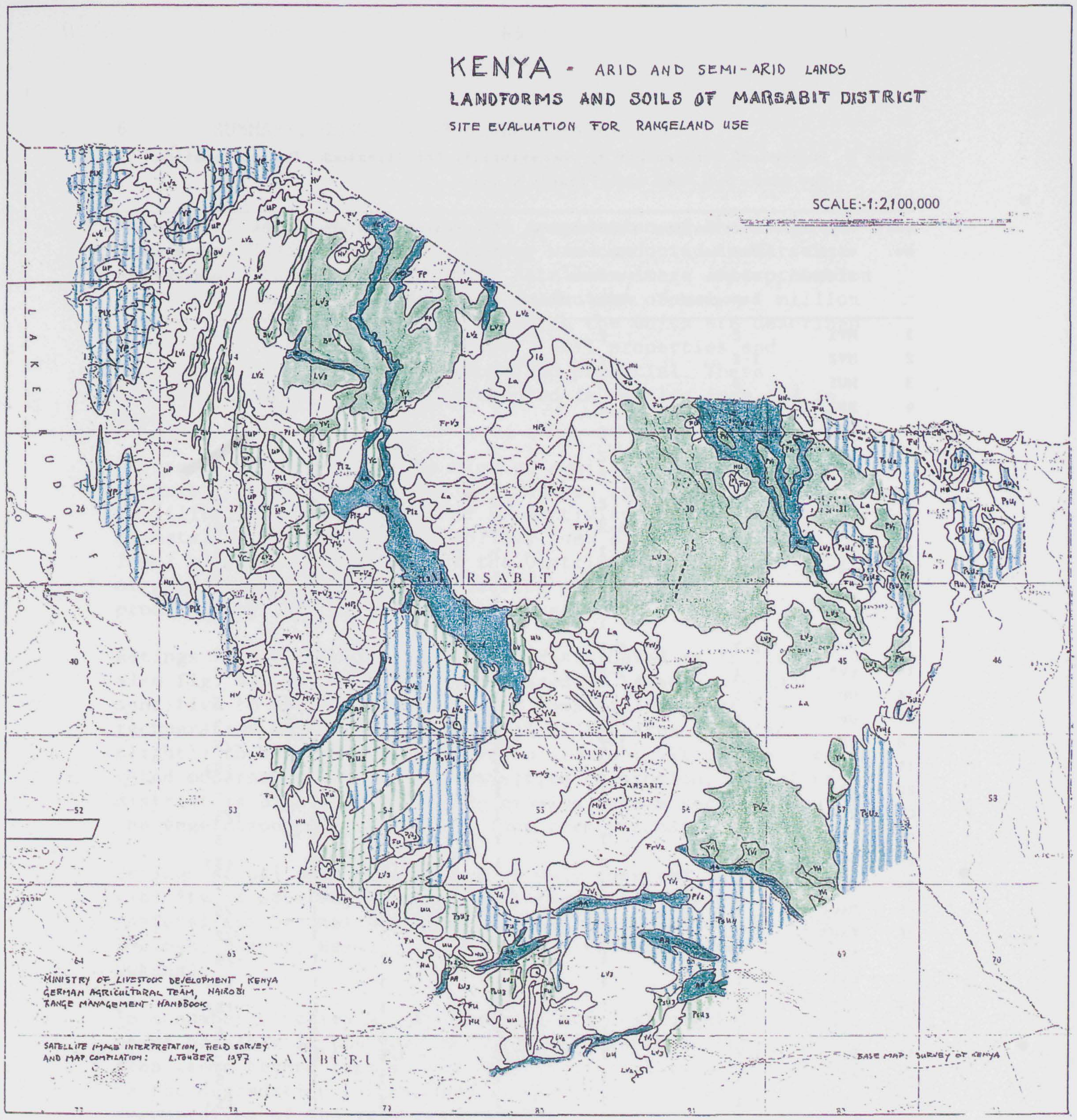


fig. 6 LIMITATIONS TO ACCESSIBILITY: TEMPORARY WET SEASON CONSTRAINTS IN ADDITION TO YEAR-ROUND LIMITATIONS - SEE ALSO FIG.

DISTRIBUTION OF MAP UNIT RATINGS - SEE TABLE 3

- NO ADDITIONAL WET SEASON CONSTRAINTS
- IN PLACES TEMPORARY LIMITATIONS DUE TO MUDDINESS / STICKINESS OF THE SURFACE
- TEMPORARY LIMITATIONS DUE TO MUDDINESS / STICKINESS OF THE SURFACE
- IN PLACES TEMPORARY LIMITATIONS DUE TO FLOODING / PONDING
- TEMPORARY LIMITATIONS DUE TO FLOODING / PONDING

Table 3 Ratings of constraints to accessibility for livestock. For explanation see para. 5.5. See also Figures 5 and 6.

| Unit no. | Mapping unit symbol | Constraints due to slope, topography | Constraints due to surface rocks, stones | Constraints in dry season for: sheep/goat | camel | cattle | Additional wet season constraints |
|---|---|---|---|---|---|---|---|
| 1 | MV1 | 2 | 2 | 1 | 3 | 3 | - |
| 2 | MV2 | 1-2 | 1 | 1 | 1 | 1 | - |
| 3 | HU1 | 3 | 3 | 4 | 5 | 5 | - |
| 4 | HP1 | 1 | 1 | 1 | 1 | 2 | - |
| 5 | HP2 | 1-3 | 1-2 | 1 | 2 | 3 | - |
| 6 | HV | 3 | 2 | 3 | 5 | 5 | - |
| 7 | FrV1 | 1-3 | 2 | 3 | 5 | 5 | - |
| 8 | FrV2 | 2 | 2 | 1 | 2 | 3 | 3 |
| 9 | FrV3 | 2 | 1-3 | 2 | 3 | 4 | 2 |
| 10 | FU | 1 | 1 | 1 | 1 | 1 | - |
| 11 | FP | 1 | 1 | 1 | 1 | 2 | - |
| 12 | FV | 1 | 2 | 1 | 2 | 3 | - |
| 13 | LV1 | 1 | 1 | 1 | 1 | 2 | - |
| 14 | LV2 | 2-3 | 2-3 | 2 | 3 | 5 | - |
| 15 | LV3 | 1 | 1-2 | 1 | 2 | 3 | 2 |
| 16 | UU | 1 | 1 | 1 | 1 | 2 | - |
| 17 | UP | 2 | 1-2 | 1 | 3 | 4 | - |
| 18 | YP | 2-3 | 1-2 | 1/2 | 1/3 | 2/5 | -/5 |
| 19 | YV1 | 1 | 2 | 1 | 1 | 1 | (5) |
| 20 | YV2 | 1 | 1 | 1 | 1 | 1 | - |
| 21 | YC | 1 | 1 | 1 | 1 | 1 | -/3 |
| 22 | PV1 | 1 | 1 | 1 | 1 | 2 | 3 |
| 23 | PV2 | 1 | 2 | 1 | 3 | 4 | (3) |
| 24 | PsU1 | 1 | 1 | 1 | 1 | 1 | - |
| 25 | PsU2 | 1 | 1 | 1 | 1 | 1 | -/5 |
| 26 | PsU3 | 1 | 1 | 1 | 1 | 1 | -/2 |
| 27 | PsU4 | 1 | 1 | 1 | 1 | 1 | -/5 |
| 28 | P11 | 1 | 1 | 1 | 1 | 1 | (3) |
| 29 | P12 | 1 | 1 | 1 | 1 | 1 | (5) |
| 30 | P13 | 1 | 1 | 1 | 1 | 1 | 5 |
| 31 | P1X | 1/5 | 1 | 1/5 | 1/5 | 1/5 | - |
| 32 | AA | 1 | 1 | 1 | 1 | 1 | 5 |
| 33 | BV | 1 | 1 | 1 | 1 | 1 | (5) |
| 34 | VC | 1/3 | 3 | 1 | 3 | 4 | 4 |
| 35 | DX | 3 | 1 | 1 | 1 | 3 | -/3 |
| 36 | La | 3 | 3 | 3 | 5 | 5 | - |

* Figures, separated by ../.. indicate respective ratings of high and low components of mapping units. Figures between brackets indicate conditions in "above average" rainy seasons.

# 6 SUMMARY, CONCLUSIONS & RECOMMENDATIONS

As part of data gathering for the compilation of the Range Management Handbook (RMH), a survey was conducted in Marsabit District on landforms and soils. Satellite image interpretation and field checks have led to the production of a 1 : 1 million scale landforms and soil map, of which the units are described in terms of topography, rock type , soil properties and landqualities pertaining to rangeland potential. These landqualities are rated and presented in tabular form and in maps.

It can be concluded that in view of available moisture storage capacity, infiltration capacity, surface stoniness and soil fertility, the rated levels of productivity (not including climate) are distributed as follows (see also fig. 3): High level of productivity: 30% of the District area Moderate level of productivity: 39% of the District area Low level of productivity: 31% of the District area.

Ratings of soil erosion hazard are distributed as follows (see also fig. 4): 11% of the District area is rated non-slightly sensitive to erosion, and has good possibilities for the recuperation of the vegetation; 31% of the area is rated slightly to moderately sensitive to erosion; 47% of the area is rated moderately to severely sensitive to erosion; 11% of the district is highly sensitive to erosion, where recuperation of the vegetation cover will be a long term process.

Serious actual soil degradation is only observed in the vicinity of waterholes, where also the settlement of pastoralists becomes permanent (Kargi, Korr, Illaut, Laisamis, Loglogo, Balesa, Kalacha, Maikona, and recently also Guz and Dukana).

In a number of cases a return of the original vegetation cover seems possible in the near foreseeable future. In others the area seems beyond repair. The type of soil plays a crucial role in the degradation process and in the possibilities for the recuperation of the vegetative cover.

Areas that are of low productivity as a consequence of climatic conditions, tend to be relatively sensitive to erosion, especially wind erosion. This is especially true on soils developed on volcanic rocks and ashes.

Restrictions in accessibility for livestock, due to rockiness, stoniness and/or steepness of the terrain are distributed as follows (see also fig. 5): no restrictions in 37% of the District area; slight restrictions in 17% of the District area; moderate restrictions in 33% of the District area; and severe restrictions in 12% of the District area.

An additional 13% of the survey area is in the wet season temporarily inaccessible due to flooding; a further 33% of the District poses possibly restrictions in the wet season due to stickiness or muddiness of the terrain (fig. 6).

During the survey it has been observed that highest grazing pressure is found on the areas of relative high potential. These are the marginal areas around the agriculturally suitable land of the Marsabit, Hurri, and Kulal hill masses, where livestock of mixed farming systems meets with pastoralist grazing. It is recommended to start more detailed reconnaissance studies into the potential of these areas, in order to come to balanced controlled stocking rates, as these areas are of crucial value to pastoralists, and in the present circumstances subject to degradation.

In order to overcome the lack of quantifiable data, studies should be conducted that lead to the knowledge of maximum sustainable carrying capacity. These studies should be carried out on a restricted number of sites that are representative in climate, soil type and vegetation for large tracts of the ASAL areas, and should be chosen on the basis of the present RMH inventories. The development of mathematical models could play a role in attaining the desired results.

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ANNEX I

Mission report

Annex 1-2

CONTENTS ANNEX I

# Annex 1-4

# 1 INTRODUCTION

In the framework of the G.T.Z.-funded Range Management Handbook Project ecological field data are gathered as part of the assessment of range potential in the Arid and Semi-Arid Lands of Kenya.

The Project is an initiative at the request of the Ministry of Livestock development, Range Department, of Kenya, and will serve land use planning and extension purposes.

The present consultancy deals with a soils and landforms inventory and the translation of these field data into factors of relevance to production level and management aspects of rangeland.

The field survey has been carried out in close cooperation with the teamleader/range specialist and the vegetation consultant, in the month of October 1987. The production of maps and report has taken place partly in Nairobi, in November-December '87 and partly in The Netherlands (STIBOKA) in December '87-January '88.

## 2 ACHIEVEMENTS

With the help of satellite imagery and the Exploratory Soil Map of Kenya (Sombroek et al., 1982) field checks have been carried out on most extensive range land types by travelling along all existing roads. Additional observations on areas otherwise inaccessible were made from light aircraft.

Initially a 1 : 500.000 scale Interpretation map has been constructed on the basis of fieldwork and satellite images, presenting 63 units of landforms and soils. This map has been reduced and simplified to a 1 : 1 million scale map of 36 units. These landform and soil units are described in terms of the following landqualities that are of influence to the performance of rangeland: water availability; soil fertility and toxicity; erosion hazard; and accessibility of the terrain for livestock. Soil and land characteristics that play a role in the landqualities and which are accordingly as much as possible recorded during the field survey are: Soil depth, stoniness, texture; topsoil structure and organic matter content, surface sealing, infiltration capacity; pH, Ca, P, K, Electrical conductivity; slope steepness, topography, temporary flooding and soil consistency during the wet season.

This field survey covers points 2 to 10 of the terms of reference; while the report and maps provide for the outcome, point 11. Point 1 of the terms of reference mentions the Exploratory Soil Map of Kenya and expresses the wish that the consultant should interprete and simplify the map in grouping related soils that have similar characteristics as to range performance for the total ASAL area.
The field experences in Marsabit have shown that:
1 The Exploratory Soil Map, being an overview of the soils of the whole country, is valuable as a first orientation but that at district level a considerable number of unit boundaries had to be corrected, and some unit descriptions to be changed;
2 It is not possible to translate the unit descriptions into qualities of relevance to range potential without thorough field checks. Accordingly it was decided in a meeting between Dr. Walther, Drs. Van de Weg (STIBOKA) and the soil consultant that such interpretation of the Exploratory Soil Map for all ASAL Districts as meant under point 1 of the terms of reference would appear an academic excercise rather than the production of a document with practical value (see annex 4).

Annex 1-8

## 3 CONSTRAINTS

The interpreted data are mostly expressed as limitations to productive capacity or to management possibilities. These are presented in qualitative terms only. It is in this stage unfortunately not possible to express for instance "Erosion hazard" in quantitative terms (e.g. less than *x* ha per S.U. will, due to wind erosion hazard, cause such soil degradation, that a point of no return is reached in *y* no. of years). Erosion hazard, production capacity of the soil and accessibility for livestock are expressed on maps in comparative terms only: ie unit A is "better" than unit B in respect of a certain landquality.

A solution to this problem however, is beyond the project set up of the Range Management Handbook. The technical Report contains some recommendations in this field.

## 4 RECOMMENDATIONS FOR FUTURE DISTRICT SURVEYS

In view of the experience with the restricted value of existing soil information as contained in the Exploratory Soil Map (see par. 3: Achievements) it is indispensible to conduct field surveys in each of the Districts to come to a sensible "gues stimate" of range potential. In view of the number of Districts to cover and consequent total project duration, it cannot be recommended to spend more than an average of 3 months consultancy time on each District.

It is foreseen however that for Districts like Wajír and Mandera relatively less information is existing compared to Marsabit (part of which is covered by the IPAL project data) and that hence for those districts more time for field data gathering will be needed. At the same time it is foreseen that reporting will need comparatively less time as, most probably, a standard format of district-wise presentation will have been developed.

Hence the proposal is to spend within a three-months consultancy at least six weeks field survey, divided in two periods of three weeks each, the first period preceded by a week of satellite image interpretation; the second period preceded by corrections on the interpretation, according to preliminary findings in the field. The rest of the consultancy time is probably sufficient for reporting.

In view of the strong relationships between landforms, soils and vegetation distribution, it is recommended that also in future surveys all fieldwork for both soils and vegetation inventory be carried out simultaneously at the same locations of observation.
However in view of the unreliable timeliness of rainy periods, the scheduling of fieldtrips should be allowed flexibility. Hence it is recommended that the budget for travel costs will meet this requirement by allowing the standard amount (year-ticket, business-class tariff) to be used for low-budget travel arrangements, so that one "district-consultancy-period-budget" allows for two trips to Kenya, if needed.

It is further recommended that consultants on resource inventory (Climate, soils, vegetation) attempt to integrate data within the consultancy period so as to produce a first draft consensus on a more quantified "guesstimate" on the distribution of carrying capacity levels of the various range management units.

It is recommended that in an early stage a detailed layout (table of contents) of the Range Management Handbook be developed, with some text examples, so as to be able to produce survey findings in a form that complies with the RMH, and does not require major effort in editing in a later stage.

Wageningen, STIBOKA January 1988

## ANNEX 2: Itinerary

| | |
|---|---|
| 15 sep-23 sep | Preparatory phase, STIBOKA, Wageningen |
| 24 sep | Departure KL 591 Amsterdam-Nairobi |
| 25 sep | Arrival Nairobi. Discussions Mr. Weeda, Kenya Soil Survey on equipment to be borrowed and selected from KSS store. |
| 26 sep | Purchase additonal equipment. Meeting with Dr. Walther. |
| 28 sep | Visit to Neth. Embassy; visit to G.A.T. Office, meeting with Dr. Fitter. Purchase of food supplies, preparation of vehicle. |
| 29 sep | Meeting at Min. of Livestock Dev. : Dr. Chege. Preparation field trip. |
| 30 sep | Departure Nairobi; arrival Maralal |
| 1 okt | Departure Maralal; arrival Baragoi |
| 2 okt | Departure Baragoi; arrival Loyangalani |
| 3 okt | Departure Loyangalani, field checks Loyangalani-Elmolo Bay-Guz-North Horr Arrival Catholic Mission North Horr. |
| 4 okt | North Horr-Guz-North Horr field checks |
| 5 okt | Field checks : North Horr-Nyaber Waterhole. |
| 6 okt | Field checks: North Horr-Balesa. |
| 7 okt-11 okt | Field checks: North Horr-Dukana-Sabarei-Ileret-Sibiloi-North Horr. |
| 12 okt | Roundtrip by air: Western part of Marsabit District. |
| 13 okt-15 okt | Field checks: North Horr-Guz-Balesa Kulal-Illaut-Korr-Kargi-Chalbi-North Horr. |
| 16 okt-17 okt | Field checks: North-Horr-Dukana/Sabarei oil company cutlines. |
| 18 okt | Comparison field data and satellite image interpretation. |
| 19 okt-21 okt | Field checks North Horr-Hurri Hills-Farola-Turbi-Sololo-Moyale-Debel. |
| 22 okt-23 okt | Field checks Debel-Moyale-Sololo-Turbi-Marsabit. Visit to KALRES. |
| 24 okt-25 okt | Field checks Marsabit-Kalacha and Marsabit-Kargi. |
| 26 okt | Visit to KALRES and Range Division staff, Ministry of Livestock Development, Marsabit. Field checks East side Mt. Marsabit. |
| 27 okt | Field checks Marsabit-Loglogo Area. |
| 28 okt | Comparison field data and satelite image interpretation. |
| 29 okt | Roundtrip by air: Eastern and North-eastern part of Marsabit District. |
| 30 okt | Field checks Marsabit-Korr-Laisamis. |
| 31 okt | Departure Marsabit-Isiolo-Meru-Embu-Nairobi. |

| | |
|---|---|
| 1 nov-10 dec | Finalisation satelite image interpretation; Map preparation-legend construction; description of mapping units. |
| 14 nov | Meeting Dr. Walther (G.A.T.), Drs. v.d. Weg (STIBOKA), Ir. Weeda (KSS) on presentation of results. |
| 19 nov | Visit to Mr. Bake, DC PAC, UNEP. |
| 11 dec | Departure Nairobi-Frankfurt-Amsterdam. |
| 14-31 dec | Finalization report. |

ANNEX 3: Terms of Reference

Terms of Reference for

Consultancy on soil science for identifying Ecological Units /Rangeunits in Marsabit District ans in preparation of a more generalized soil map of the ASAL Areas in northern Kenia.

Background :

1. The present soil map of Kenya (Sombroek;Brown; van der Pow ,1980) shows a wide variety of soils even those which are somehow related. The area concerned is the northern part of the arid fringe of Kena.
2. A grouping of related soils,especially the top soil layer ( up to 50 cm depth ) seems to be a appropriate means for easy use by related persons in the field ,such as government personnel from the Ministies as was as the districts.This might be a a very helpful tool,since some of the closely re - lated soils bear nearly identical vegetation. ( e.g. Korr Area;SW Marsabit District!Soips classi - fied as Ps 9 /Ps 10 /Y 10,)
3. The vegetation and related soil types (of a broader snense ) will form,together with informations on rainfall pattern e Rangeland - / Ecological Unit,out of which the productivity of biomass might be calculated more precisely. The planning of the constrains of those pruduction area is hoped to be improved.
4. A close cooperation with the vegetation -/Rangeland- specialists and the climatologist is obligatory.

Annex 3-2

16.10.87

## Duties of the consultant in soil ecology

1. Draft-generalisation of the soil map of the northern ASAL Areas of Kenya should be based on Sombroeks (et alii,1980 ) soil map.The aspects of grouping together soils which are more or less related should be done under the practical use of the 'new' easy understandable soil map.
   The following Districts must be included: Marsabit!Waijr; Mandera;Garissa;Tana River;Samburu ;Isiolo.

   For Marsabit a definite map must be produced,as the study is mainly concentrating on this District.

2. Field work will prove desk work on soils
3. Field work will iclude certiefied spatial occurance of generalized soil types even in more than one land unit.
4. To point out erodibility or performance to erodibility and erozion hazards by Wind / Water
   This is necessary for the number of stock which might be considered to use one specific area.
5. to improve knowledge on soils during field work,whenever possible ,especially in respect to soil fertility,which might effect growing performance of forage plants.
6. At least information on the performance (soil fertility,etc) of eroded soils should be given.
7. Recommendations should be given where to protect the soil (of which soil type and Rangeunit ).
8. Geomorphological occurrance of the major units such as slope gradients,exposure should be included
9. to assist in mapping Range units (vegetation included)
10. to cooperate with the other scientists especially during field work.

11. OUTCOME :
    1. a generalized draft map of related soils of the indicated areas.
    2. description of the newly grouped soils which is easily understandable and usable by related (NON soiltrained) personnel.
    3. a description of soil fertility - if possible with the present informations available and the informations collected during field work and its consequences for the use of a particular Range.
    4. a generalized map of Marsabit District.
    5. a concise description on the grouped soils of Marsabit district
    6. suggestions for further work/research

NOTE: If it is necassary to get analysis of soils - esp. soil fertility,arrangements with N.A.L. and KSS will be

ANNEX 4
From: Report on a backstopping mission to Kenya
by R.F. v.d. Weg, STIBOKA

## 4. RANGE MANAGEMENT HANDBOOK (RMH)

Following discussions earlier this year (see backstopping mission report, June 1987) Stiboka was requested to carry out the soil studies for the Marsabit district in the framework of the work for the Range Management Handbook of the semi-arid to arid areas of Kenya. The Ministry of Livestock Development, Range Division is responsible for the work, assisted by the German Agricultural Team. The FRG is funding the project. Dr. D. Walther is in charge of the study including coordination and write-up.

In 1983 the "Farm Management Handbook" covering the medium to high potential areas of Kenya were published by GTZ. The RMH is dealing with the semi-arid to arid areas of Kenya. It will be published in three parts:
I. General information, purpose, methodology
II. District reports
III. Special studies on various topics.

The district reports will cover Turkana, West Pokot, Marsabit, Baringo, Sambaru, Kajado, Wajir, Mandera, Isiolo, Garissa and Tana River all those district which were not covered by the Farm Management Handbook. Each district report will contain informat-ion on soils, climate vegetation, population (human and cattle), land use, socio-economic data, and will give guidelines for proper land use. They are meant to be used in particular by the Range Management Division Staff of the Ministry of Livestock Development in particular by the extension staff. The project started officially early 1987 and the work will be carried out district by district. Work on Marsabit district started in August 1987. For Marsabit district the climate studies are carried out by Prof. Jaetzold (University of Trier), the vegetation studies by Dr. Schultka (Giessen, Germany), the soil studies by Drs. L. Touber (Stiboka) in cooperation with the Kenya Soil Survey. In July tensitive Terms of Reference for the soil studies were drawn up, subject to change however as was indicated at that time, if found not feasible as the soil study progressed. Tauber started preparatory work on September 15, and left for Kenya on September 23. Field work in the area was carried out from 1-31 October.

On November, 14, the progress of the work was reviewed during a meeting with Dr. Walther, Drs. Touber, Ir. Weeda and Drs. Van de Weg.

For the soil study use is made of all available existing information on soils, geology, vegetation etc. and Landsat images. Basic soil information is available on 1:1M scale (Exploratory Soil Map of Kenya, 1982). Additional soil informat-ion is collected during field surveys including a number of soil samples, to be analysed at NAL. Soil and vegetation field survey for the Marsabit area were carried out together by the soil and vegetation expert.

Following the field survey in the Marsabit area it was found that the Exploratory Soil map of Kenya does not give enough accurate information (even not at that scale) neither on the location of the map units, neither in the description of the soil mapping units, to be used as a basis for the preparation of the derived "rangeland management units" (see below).
For that reason it was decided not to embark on the "draft-generalisation" of the Exploratory Soil Map, as stipulated under item 1 of the ToR. Such a map will be of pure academic use, since the fieldwork in the Marsabit district has proved, that for the purpose of range management a concise site evaluation survey is needed. Recommendations which will be given will have tube largely derived from the surveys carried out. However, the 1:1M exploratory soil map is valuable as a orientation for field surveys in the various districts.

A "landform and soils" map of Marsabit district is being prepared at a scale of 1:500.000, together with an elaborate legend and separate map-unit descriptions with information on landforms, soils, relief, erosion characteristics etc. (about 63 units). This map (black/white) will be fair drawn with map unit symbols, and be kept as "internal document". A transparant copy should also be given to KSS. This map will be reduced to a scale of 1:1M, and some generalization will be made. Tauber will prepare based on the "soils and landform map" a map showing "land qualities" (combination of mapping units) however at this moment not taking into account climate and vegetation features.
Based on this map and the vegetation survey and the climate data as separate studies, a map on 1:1M scale will be prepared indicating "range management units" showing land qualities, for rangeland management purposes. This maps in particular is meant for the extension staff. Due attention will be given for the concise description of these units, in such a way that it will be easily understandable for the "layman" user.

Soil map and "Range units" map will be printed in colour. Discussions were held on November 17. with Mr. Da Souza, Department of Geography, University of Nairobi on the map preparation. He will start to prepare a 1:1M base map derived from the 1:1M topographic map of Kenya (corrections, additions via D. Walther). Touber will prepare soil map including colour selection. The Topographic base including screens will be in gray, soil boundaries and symbols in black, Van de Weg will supply some screens. The legend will be given on a separate sheet, including map unit symbols and colour indication blocks.

Soil, vegetation and climate studies will have to be coordinated in the near future. A tentative time schedule has been indicated:
- Soil and vegetation study: January 1988 (Giessen)
- Soil, vegetation and climate study: February 1988 (Trier?)
- Presentation of data to Kenya Government Authorities (first week of March 1988).

During 1988 further studies and research for Marsabit district will be carried out on population, land use data, livestock assessment, socio-economic data etc. The report is to be published at the end of 1988. It is therefore unlikely that the studies for other district will start earlier than January 1989.

Touber will prepare a short "terminal report" at the end of his assignment (to be approved by Dr. Walther and to be forwarded through Stiboka to GTZ HQ) stipulating progress of work, methodology, and suggestions for further research studies, proposals for improved methods of work etc.